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[54] METHOD OF OPERATING A HIGH-PRESSURE
GASEOUS DISCHARGE LAMP WITH IMPROVED
EFFICIENCY
6 Claims, 11 Drawing Figs.

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315/165, 315/172, 315/176
[51] Int. Cl. H05b 37/00,
H05b 41/16
[50] Field of Search. 307/2;
315/165, 171, 172, 176, 209, 246; 340/331

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3,156,826 11/1964 Mutschler 307/2 X

ABSTRACT: The efficiency of a conventional high-pressure gaseous discharge lamp, such as a 400 watt mercury-vapor lamp, is increased by pulse-operating the lamp at power loadings which are higher than the average rated power input of the lamp. The high-power pulses are of such magnitude and duration that the resultant average power input does not exceed the power loading for which the lamp is designed and rated. This is achieved by generating a series of high-voltage pulses with a suitable circuit and applying the pulses to the lamp electrodes. Optimum results in the case of conventional high-pressure mercury-vapor discharge lamps having ratings of from 100 to 1,000 watts are obtained with pulses that have a magnitude of from 60 to 600 volts, are 0.2 to 5 milliseconds in duration and have a repetition rate of from 50 to 500 pulses per second. In order to prevent arc extinction between pulses, the latter are preferably superimposed on a "keep-alive" DC potential that constitutes from three to 20 percent of the rated average power input of the lamp.

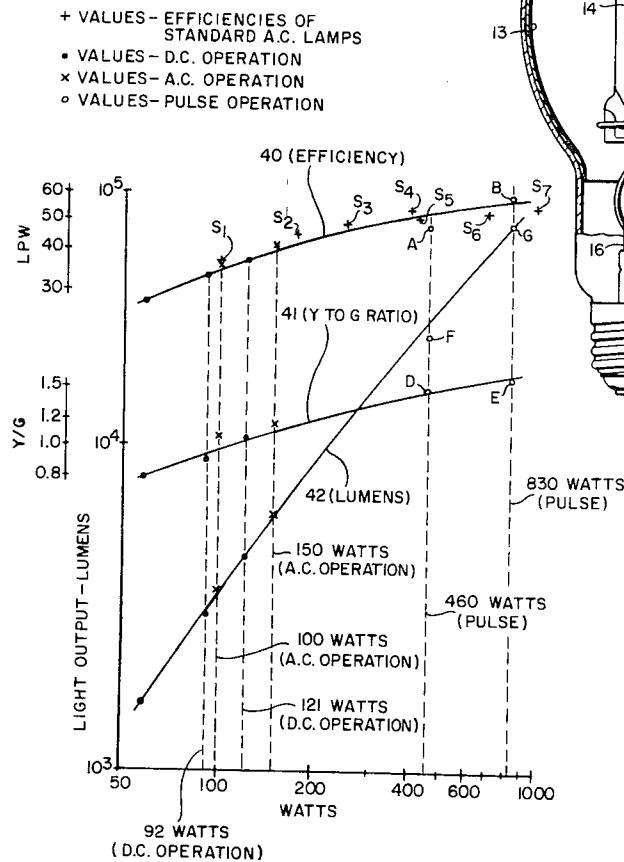
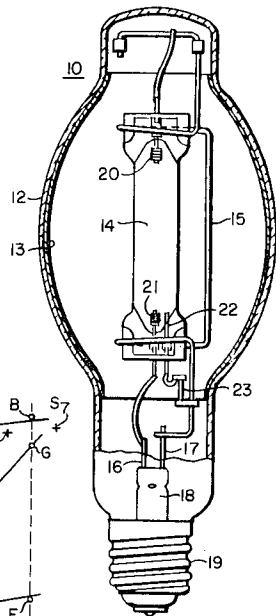
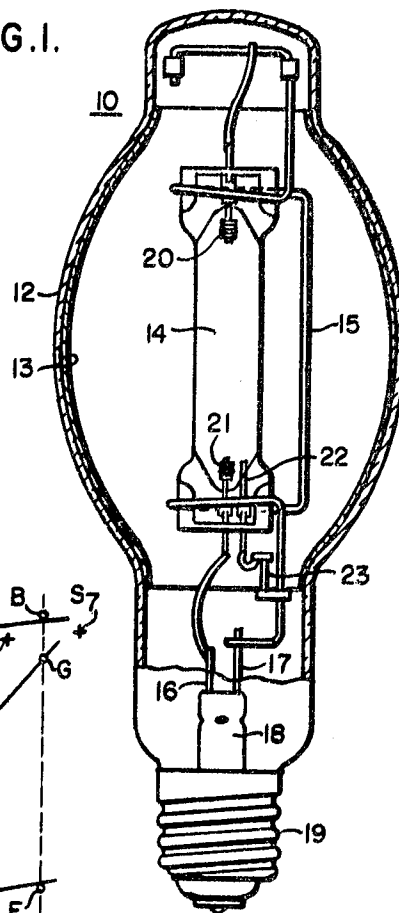


FIG. 1.



- + VALUES - EFFICIENCIES OF STANDARD A.C. LAMPS
- VALUES - D.C. OPERATION
- x VALUES - A.C. OPERATION
- VALUES - PULSE OPERATION

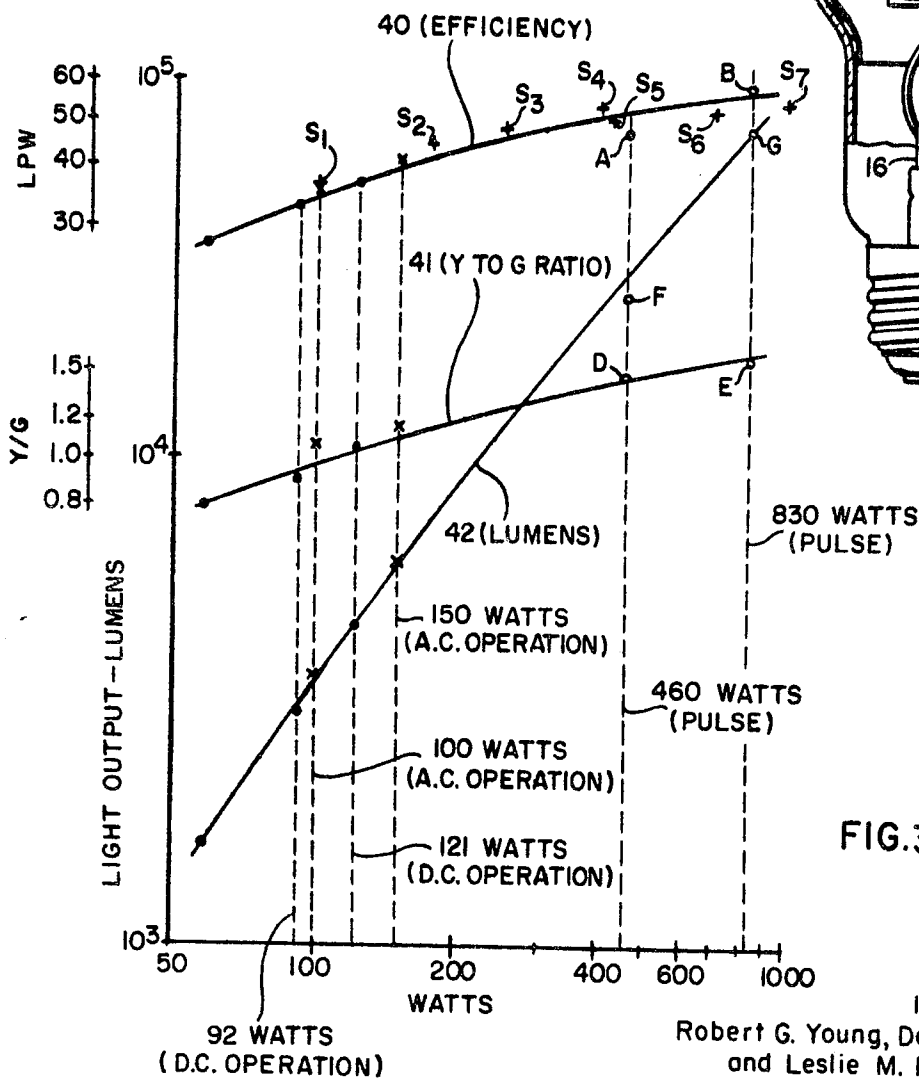
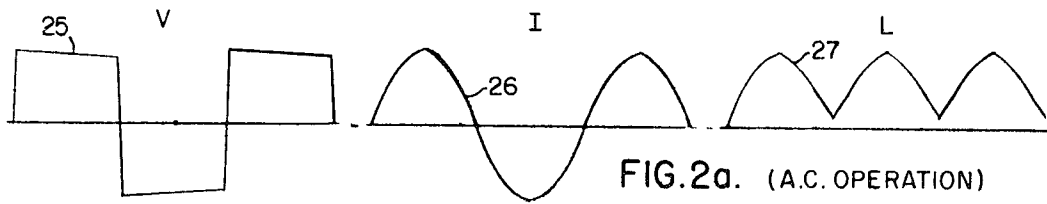
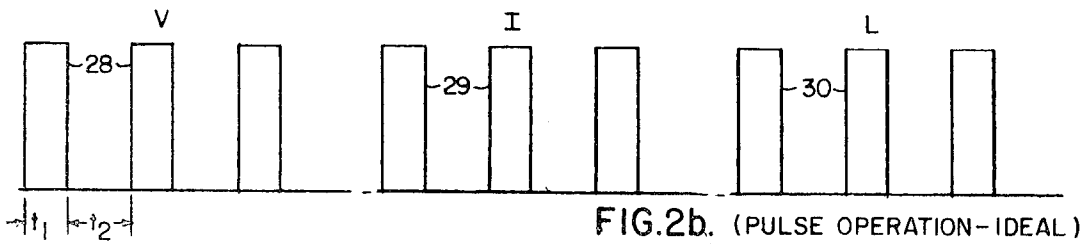
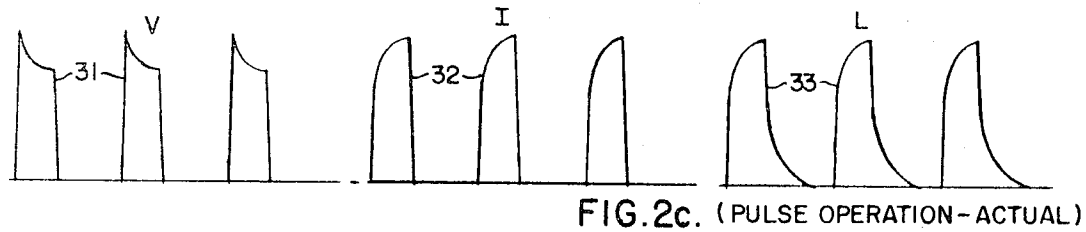
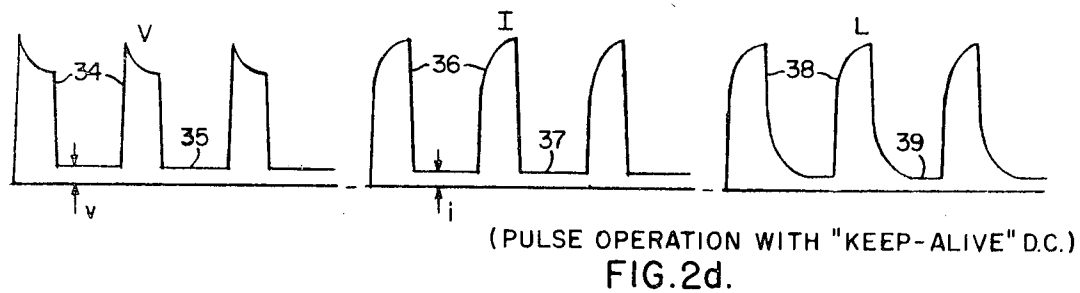
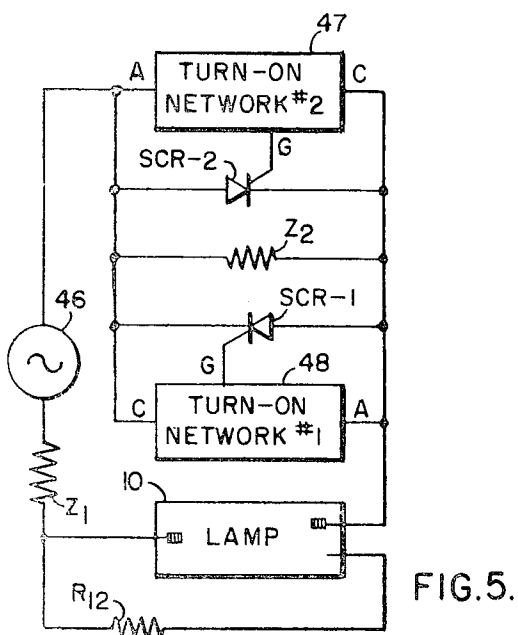
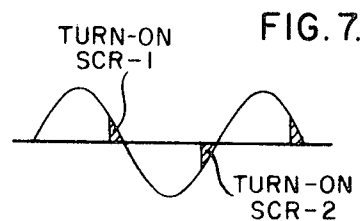
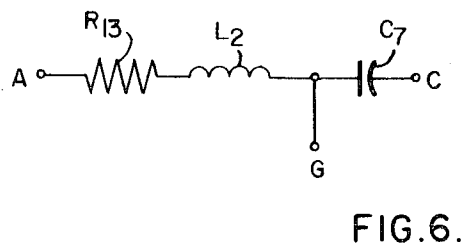


FIG. 3.

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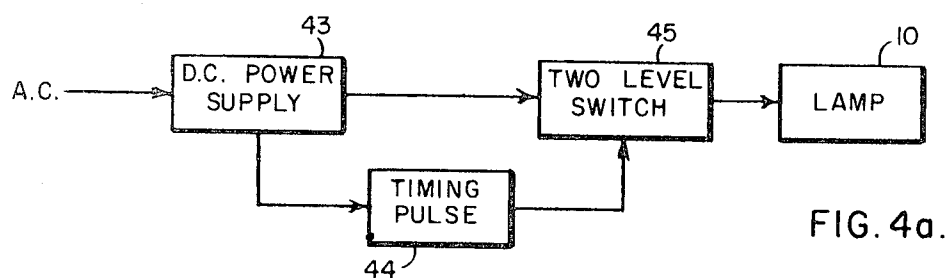
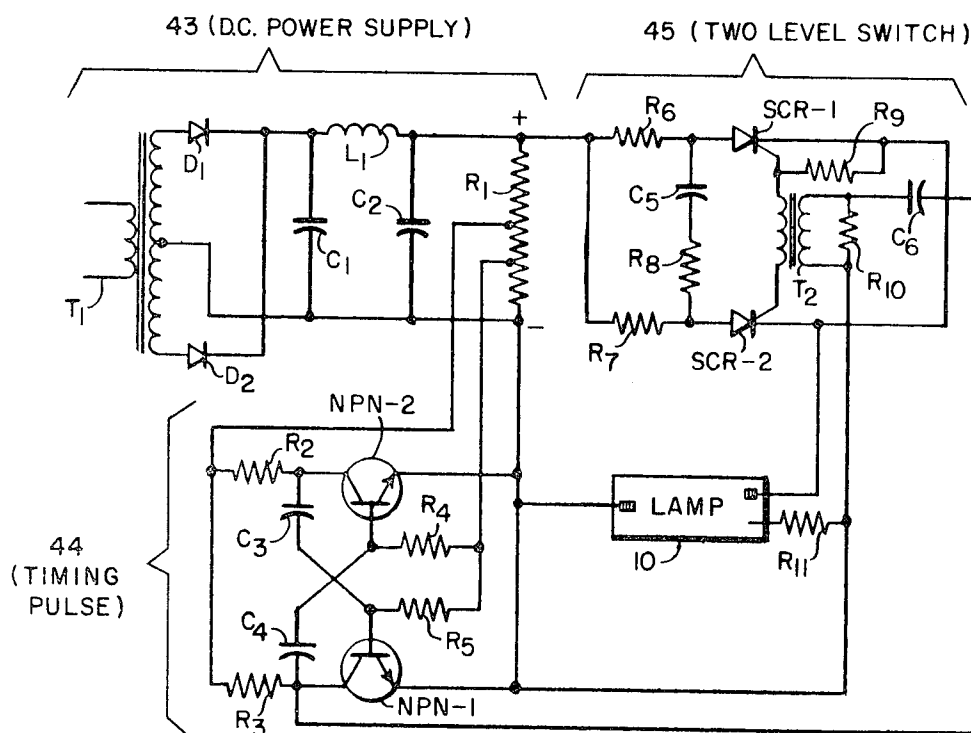


FIG. 4b.

METHOD OF OPERATING A HIGH-PRESSURE GASEOUS DISCHARGE LAMP WITH IMPROVED EFFICIENCY

ACKNOWLEDGMENT OF GOVERNMENT CONTRACT

The invention herein described was made in the course of and under a contract with the Department of the Army.

CROSS-REFERENCE TO RELATED APPLICATION

The present invention is related to the subject matter of pending application Ser. No. 795,258 filed Jan. 30, 1969 by Robert G. Young, now U.S. Pat. No. 3,551,738.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to gaseous discharge lamps and has particular reference to an improved method of operating high-pressure mercury-vapor discharge lamps of conventional construction that are designed to operate at a predetermined wattage.

2. Description of the Prior Art

High-pressure mercury-vapor discharge lamps are well known in the art and are conventionally operated on a 60 Hertz alternating-current power supply. The lamps are designed to operate continuously at a predetermined wattage rating and the power supply and ballast are designed to provide a power input which does not exceed this wattage rating.

In order to achieve the maximum output of light with the minimum amount of electrical power, such lamps are constantly being improved to enhance their operating efficiency. The concept of pulse operating arc discharge lamps to increase their light output is per se well known in the art. In U.S. Pat. No. 3,156,826 issued Nov. 10, 1964 to E. C. Mutschler there is disclosed, for example, a light communication system wherein a high pressure arc discharge lamp is operated on pulsating direct current. The pulse frequency is 800 Hertz and the pulses are superimposed on direct current of much lower magnitude which maintains the arc discharge when the lamp is in its "quiescent" state. The lamp is operated on the high current pulses when it is desired to transmit light signals, such as Morse Code on board a ship, and is operated on the low direct-current power level when in the nonsignalling or quiescent state. Pulse operation of low-pressure fluorescent lamps wherein the lamp is momentarily overloaded to provide an intense flash of light for picture taking purposes is also known and is disclosed in Canadian Pat. No. 738,564 issued July 12, 1966. While the principle of pulse operating gaseous discharge lamps is per se known in the art, the principle was heretofore employed to operate the lamps in this fashion for relatively short periods of time—for example, while the lamp was being used for communicating purposes or as a photoflash light source.

SUMMARY OF THE INVENTION

It is accordingly the general object of the present invention to provide a method of operating conventional high-pressure gaseous-discharge lamps continuously at an efficiency heretofore unobtainable without exceeding the average rated power loading for which the lamps are designed.

Another and more specific object is the provision of a method of operating conventional high-pressure mercury-vapor lamps in a manner such that their efficiency and the intensity of yellow radiation compared to the green radiation are increased without exceeding the average rated power input of the lamps.

The foregoing objects and other advantages are achieved in accordance with the present invention by operating the lamp on a power source which continuously applies high voltage pulses to the lamp electrodes at a selected rate or frequency. The pulse frequency is in the range of about from 50 to 500 pulses per second and the pulses are of such magnitude and duration that the light output and efficiency of the lamp are increased without exceeding the average power input or wattage

loading for which the lamp is rated. The pulses are generated by a suitable operating circuit that is energized by a conventional 60 Hertz alternating-current power source. The magnitude and frequency of the voltage pulses are so correlated that the average power input supplied to the lamp does not exceed that for which the lamp was designed, even though the lamp is continuously operated in a pulse mode. The high-voltage pulses are desirably superimposed on a low-level DC voltage to prevent the arc from extinguishing between pulses.

BRIEF DESCRIPTION OF THE DRAWING

A better understanding of the invention will be obtained by referring to the accompanying drawing, wherein:

FIG. 1 is an elevational view, partly in section, of a conventional 400-watt high-pressure mercury-vapor discharge lamp which is representative of the type of lamp that can be pulse-operated in accordance with the concepts of the present invention;

FIG. 2a is a graph illustrating the voltage, current, and light output characteristics of such a lamp when conventionally operated on a 60 Hertz alternating-current power supply;

FIG. 2b is a similar graph illustrating the voltage, current and light output characteristics of the lamp under ideal pulse-operating conditions;

FIG. 2c is a graph illustrating the aforesaid characteristics achieved with pulse operation under actual conditions;

FIG. 2d is a graph depicting the voltage, current and light output characteristics of the lamp when pulse operated under actual conditions in combination with a "keep-alive" DC voltage;

FIG. 3 is a composite graph comparing the light output, ratio of yellow to green radiations and efficiency characteristics of a 100-watt high-pressure mercury-vapor discharge lamp when operated in a pulse mode in accordance with the invention and at various power inputs on alternating current and on direct current;

FIG. 4a is a block diagram of a suitable circuit for pulse operating the lamp in accordance with the present invention;

FIG. 4b is a schematic diagram of an actual circuit incorporating the features shown in FIG. 4a,

FIG. 5 is a schematic of an alternative pulse-generating circuit;

FIG. 6 is a schematic diagram of a suitable network for controlling the SCRs in the circuit shown in FIG. 5; and

FIG. 7 is a graph illustrating the manner in which the network shown in FIG. 6 controls the operation of the respective SCRs.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 there is shown a 400-watt high-pressure mercury-vapor discharge lamp 10 of conventional construction which is typical of the family of lamps that can be pulse-operated in accordance with the concepts of the present invention. Such lamps are made and marketed in various sizes ranging from 100 to 1000 watts. The lamp 10 consists of the usual outer glass envelope or jacket 12 that may be provided with a suitable color-correcting phosphor coating 13 on its inner surface and contains a quartz arc tube 14. Such phosphors are well known in the art. The arc tube 14 is suspended within the outer envelope 12 by a suitable support structure such as a wire harness 15 that is coupled to the sealed ends of the arc tube and extends therebeyond into the domed end of the envelope 12. The opposite end of the wire harness 15 is fastened to one of a pair of rigid lead wires 16, 17 that are sealed through a glass stem 18 which is fused to the envelope neck in accordance with standard lampmaking practice. The outer ends of the lead wires 16, 17 are connected to the contacts of a suitable base member 19. The inner ends of the lead wires 16, 17 are electrically connected to the main electrodes 20, 21 and starting electrode 22 of the arc tube 14 by the usual arrangement of auxiliary conductors and a starting resistor 23.

The arc tube 14 contains a charge of mercury (66 mg. in the case of the 400-watt lamp here shown) and a suitable starting gas, such as argon at a pressure of 25 torr.

Such conventional mercury-vapor lamps are normally operated on an iron core ballast and a 60 Hertz alternating-current power supply. As is shown in FIG. 2a, with this mode of operation the resulting voltage pulses 25 applied to the main electrodes 20, 21 are generally square shaped. There are 120 pulses per second and the pulses are approximately 8 milliseconds in duration. The current pulses 26 are generally sinusoidal and the light output L consists of a similar number of pulses 27. Since the time between pulses (that is, the time between the extinction and reignition of the arc) is only a small fraction of a millisecond, the electron and gas temperatures do not cool sufficiently to terminate the visible radiation before the next half of the cycle begins. This radiation consists almost entirely of yellow (5770A., 5790A.) and green (5460A.) lines and does not fall below about 10 percent of its peak value at any time during the cycle, as shown in FIG. 2a.

In contrast, the present invention enhances the light output and efficiency of the lamp by operating it at a high power loading for a predetermined period of time during each cycle. The frequency, duration and magnitude of the high-energy pulses are so correlated that the rated average power input of the lamp is not exceeded. This is accomplished by applying a series of high-voltage pulses to the lamp electrodes 20, 21 which supply a high power input to the lamp for a short period of time and no power to the lamp for a longer period of time. FIG. 2b illustrates the waveforms of the lamp voltage V, current I and light output L in the case of an idealized lamp that corresponds to square-shaped voltage pulses 28. As shown, the pulse duration (t_1) is shorter than the time (t_2) between pulses. The lamp current I and light output L in such an idealized case would consist of an identical number of pulses 29 and 30, respectively, of the same shape and frequency.

Of course, the waveforms are somewhat different in actual practice. As shown in FIG. 2c, the voltage pulses 31 have spiked leading edges and concave tops whereas the current pulses 32 have convex tops and tapered or rounded leading edges. The light pulses 33 are of the same general configuration as the current pulses 32 except that their trailing edges are sloped or tapered rather than terminated abruptly. As will be noted, the pulse rate is such that the arc electron and gas temperatures cool sufficiently between pulses to extinguish the arc with the result that the light output vanishes between pulses. As a specific example, such arc extinction will occur if the pulse duration t_1 is 1 millisecond and the time between pulses t_2 is 9 milliseconds (a 10 percent duty cycle).

As shown in FIG. 2d, arc extinction between pulses can be prevented by superimposing the voltage pulses 34 on a DC voltage 35 of magnitude "v." The current pulses 36 are, accordingly, superimposed on a small current 37 of magnitude "i" that continuously flows through the lamp and constitutes a "keep-alive" current that prevents the arc from extinguishing. The light output L is thus maintained at a low level 39 between the light pulses 38.

As a specific example of the pulse magnitude, pulse repetition rate or frequency and the duty cycle found suitable in accordance with the present invention, the voltage pulses applied to the lamp electrodes 20, 21 can vary within a range of from 60 to 600 volts, the pulse repetition rate is maintained within a range from about 50 to 500 pulses per second and the duty cycle ranges from 5 percent to 25 percent. The specific values for each of these parameters will, of course, vary depending upon the physical dimensions of the arc tube, the type of fill gas employed, etc. and the rated wattage of the lamp. The high-power pulses are so correlated with respect to the wattage rating and rated average power input of the lamp that the ratio of the instantaneous power input to the rated average power input is maintained within the range of 2:1 to 20:1. The direct-current keep-alive voltage is maintained within a range of about 50 to 250 volts, depending on the particular type of lamp involved. This keep-alive voltage is also correlated with

the wattage rating of the lamp and is of such value that the resultant power input constitutes from about 3 to 20 percent of the rated average power input of the particular lamp involved.

The term "duty cycle" as used herein and in the appended claims refers to the percentile length of time the pulses are applied to the arc tube electrodes 20, 21 over a given period of time. For example, if the high-power pulses are 1 millisecond in length and there are 9 milliseconds between pulses, then the duty cycle is 10 percent. Conversely, if the pulse duration is 2 milliseconds and there are 8 milliseconds between pulses, then the duty cycle is 20 percent.

The improvement in light output, efficiency, and the ratio of yellow to green radiations obtained by pulse-operating a conventional high-pressure mercury-vapor discharge lamp in accordance with the present invention is illustrated graphically in FIG. 3. The data on which the various curves are based was obtained by operating an arc tube which had a wattage rating (that is, a rated average power input) of 100 watts and was mounted within a clear outer envelope. The arc tube contained 10 milligrams of mercury and argon at a pressure of 25 torr. The lamp was operated on direct current, on 60 Hertz AC current and on a low "keep-alive" direct current with superimposed high voltage pulses. As will be noted from curve 40, the efficiency of this particular lamp was approximately 28 lumens per watt when the lamp was operated on direct current at a power loading of 58 watts. The efficiency increased to approximately 33 lumens per watt when the lamp was operated on DC at a power loading of 92 watts and was 37 lumens per watt when the DC power loading was increased to 121 watts (approximately 20 percent overloading).

In the case of 60 Hertz alternating-current operation, the lamp efficiency was approximately 36.5 lumens per watt when the lamp was operated at its rated power loading of 100 watts. The efficiency increased to about 41 lumens per watt when the AC power loading was increased to 150 watts (50 percent overloading).

In contrast, when the lamp was energized continuously with high-voltage pulses that produced an instantaneous power loading of 460 watts, the lamp operated at an efficiency of 47 lumens per watt (point A in FIG. 3). The efficiency increased to 58 lumens per watt when the lamp was operated on pulses that provided an instantaneous power loading of 830 watts (point B). The instantaneous power loadings of 460 watts and 830 watts were 5 and 9 times greater, respectively, than the power input of 92 watts used in the case of DC operation. As will be noted, the 830 watt pulses produced an efficiency (58 lumens per watt) which is 59 percent higher than the 36.5 lumens per watt efficiency (S_1 in FIG. 3) which 100-watt mercury-vapor lamps exhibit when conventionally operated on AC at their rated wattage. The pulses used in this particular case had a magnitude of approximately 90 volts, approximately 9 amps, and a duration of 2 milliseconds. The pulse rate was 60 pulses per second and the duty cycle was 12 percent. The pulsed loading of 460 watts was achieved with pulses of approximately 90 volts and 5 amps. The pulses were 2 milliseconds duration, had a repetition rate of about 110 pulses per second and the duty cycle was 22 percent. The average power input applied to the lamp was 100 watts in both of the aforesaid cases of pulse operation.

For comparison purposes, the established efficiencies of standard high-pressure mercury-vapor discharge lamps of various wattages when operated on AC current at their rated wattage are plotted along the efficiency curve 40 in FIG. 3. As will be noted, a standard 100-watt lamp when thus operated at its rated wattage has an efficiency of 36.5 lumens per watt (point S_1). A standard 175-watt lamp when conventionally operated on AC at its rated wattage has an efficiency of 45 lumens per watt (point S_2). The corresponding efficiency values for a 250-watt lamp, a 400-watt lamp, a 425-watt lamp, a 700-watt lamp and a 1000-watt lamp are 48 lumens per watt, 54 lumens per watt, 51 lumens per watt, 53 lumens per watt, and 55 lumens per watt, respectively, (points S_3 through S_7 in FIG. 3).

Thus, the present invention permits a lamp that is rated for continuous operation at a power loading of 100 watts, for example, to be pulse-operated at an efficiency that is as high as that of a standard 1000-watt AC lamp without exceeding the rated average power input of 100 watts.

The ratio of the yellow to green radiations (Y/G) produced by the pulse-operated lamp increased in a similar fashion, as indicated by curve 41 of FIG. 3. As will be noted, this ratio (points D and E, respectively) was from 39 percent to 83 percent higher in the case of the 100 watt lamp when pulse operated at instantaneous power inputs of 460 watts ($Y/G=1.5$) and 830 watts ($Y/G=1.65$) compared to the ratios exhibited when the same lamp operated at 92 watts on direct current ($Y/G=0.9$) and at 100 watts ($Y/G=1.08$) on AC current. The Y/G ratio for the pulsed lamps was from 39 percent to 53 percent higher than that exhibited by the lamp when operated on AC at its rated loading of 100 watts.

The light output increased at an even greater rate, as shown by the lumen curve 42. As indicated by points F and G (460-watt and 830-watt pulse operation, respectively), the light output was from 20 percent to 75 percent higher than that obtained with the same lamp when operated at 92 watts on direct current and 100 watts on AC current.

The keep-alive DC current on which the high-power pulses were superimposed in the case of the 100-watt lamp tests described above had a value of 0.15 amp (15 percent of the average rated power input of the lamp).

Pulse Circuits—Examples

High-power pulses of the desired magnitude, frequency and duty cycle can be obtained by various types of circuits known to those skilled in the art. As a specific example of one such circuit, satisfactory pulse operation has been achieved with a three-part circuit of the type shown in FIG. 4a. As illustrated, this circuit basically consists of a conventional DC power supply 43 that is energized from a 60 Hertz AC source. The DC power supply is connected to a timing pulse unit 44 which, in turn, is connected to a two-level switching unit 45 that is also connected to the DC power supply. The output of the circuit is applied to the electrodes of the arc discharge lamp 10 and consists of a series of high-voltage pulses of predetermined magnitude and frequency.

A schematic of a circuit based on this principle is illustrated in FIG. 4b. As will be noted, the DC power supply unit 43 is of conventional design and consists of a transformer T_1 having a secondary that is connected in full-wave rectifying relationship with a pair of diodes D_1 , D_2 ; a filter network L_1 , C_1 and C_2 ; and a load resistor R_1 . The timing pulse unit 44 is an astable or free-running multivibrator circuit. The values of C_3 , R_3 and C_4 , R_4 are made unequal so that the "on" and the "off" times of NPN-1 will be unequal. The rectangular wave output of the timing-pulse unit is fed through a differentiating network (C_6 , R_6) of the two-level switch unit 45 into a second transformer T_2 .

The various components of the two-level switch unit 45 are so correlated that the silicon controlled rectifier SCR-1 is "on" most of the time while the other rectifier SCR-2 is "off." The positive pulse from transformer T_2 turns SCR-2 "on" and the discharge pulse from C_3 turns SCR-1 "off." A few milliseconds later a negative pulse from transformer T_1 turns SCR-1 "on" again and the discharge pulse from C_3 turns SCR-2 "off." The value of the series resistance R_7 is lower than that of R_6 so that the current through SCR-2 is higher than that through SCR-1. The sum of the current through SCR-1 and SCR-2 passes through the lamp 10. By properly adjusting the ratios of C_3 , R_3 to C_4 , R_4 and R_6 to R_7 , the average current and power applied to the lamp can be held at the rated value while the pulse current is made much higher.

Since the luminous efficiency increases with current and power input, the average luminous efficiency increases as the ratio of pulsed to average current is increased. Test results have shown that the two-level switch unit 45 shown in FIG. 4b

can readily pulse a 100-watt lamp from a lamp current of 1 amp (95 volts and 92 watts) to about 9 times this current. The circuit constants in this particular case were as follows: R_6 was approximately 67 ohms, R_7 was approximately 7 ohms, R_8 was 0.1 ohm, R_{10} was 10,000 ohms, R_9 was 1000 ohms, R_{11} was 20,000 ohms, C_3 was 11 microfarads, and C_4 was 0.01 microfarad. Each SCR was a 2N685. The pulse length was 2 milliseconds and the luminous efficiency of the lamp was 33 lumens per watt at the 1-amp level and 58 lumens per watt at the 9 amps level.

Another circuit for generating high-power pulses which meet the requirements of the present invention is shown in FIG. 5. As shown, an alternating-current power source 46, which may include a step-up transformer (not shown), is connected to one of the main electrodes of the lamp 10 through a series impedance Z_1 and to the other main electrode through a pulsing unit consisting of the following components connected in parallel relationship: turn-on network No. 1, silicon controlled rectifier SCR-1, impedance Z_2 , SCR-2 and turn-on network No. 2. The series impedances Z_1 and Z_2 limit the current through the lamp to a suitably low value. For a short period of time during each half cycle, one of the SCRs is turned "on" by its associated network, thus shorting out impedance Z_2 and permitting a much higher current to flow through the lamp. The SCRs and their associated turn-on networks are reversed in polarity and accordingly operate on alternate half-cycles.

Various types of networks can be used to turn the respective SCRs "on," that is, to render them conductive. A suitable network is shown in FIG. 6 and consists of a resistor R_{13} , inductance L_2 and a capacitor C_7 that are connected in series with one another. The capacitor is connected directly to the cathode C of the SCR and the resistor is connected to the anode A of the SCR. The gate G of the SCR is connected to the network between the inductance L_2 and the capacitor C_7 . The circuit constants are so correlated that the voltage between the cathode C and the gate G of the SCR lags the voltage applied across the SCR. Late in the half-cycle, however, the voltage from the gate G to the cathode C becomes sufficiently positive to turn the SCR "on" for the remainder of the half-cycle. On the following half-cycle, that particular SCR is turned off by the voltage reversal and the other SCR is subsequently turned "on." This action is shown graphically in FIG. 7.

Various modifications can be made in the circuit shown in FIG. 5. For example, the series impedance Z_1 can be made part of a transformer at the AC power input 46 and the other series impedance Z_2 and the SCRs can be placed on the primary side of the transformer at the AC input. Thyratrons can also be substituted for the SCRs. In all cases, however, the role of the SCRs and the turn-on networks is to increase the lamp current (for example, by a factor of 10) for a fraction of each half-cycle (about 10 percent for example) and thereby increase the average luminous efficiency of the lamp while holding the average current passing through the lamp at a value which is equivalent to the rated lamp current or power loading.

A constant keep-alive DC current of preselected value can be supplied to the lamp by a separate circuit in addition to those described. A suitable circuit comprises a conventional DC power supply that is connected to one of the main electrodes of the lamp 10 through a resistor and an inductance that are connected in series, with the other side of the power supply being connected directly to the other main electrode. A keep-alive DC current network of this character is described in the aforementioned pending application Ser. No. 795,258 of R. G. Young.

It will be appreciated from the foregoing that the objects of the present invention have been achieved in that a method of operating a high-pressure gaseous-discharge lamp has been provided wherein the luminous efficiency of the lamp is greatly enhanced without exceeding the rated power input of the lamp. This is accomplished by applying a series of high-

power pulses to the lamp electrodes, which pulses are of predetermined magnitude, frequency, and have a predetermined duty cycle.

While several embodiments have been disclosed, it will be appreciated that various modifications can be made without departing from the spirit and scope of the invention. For example, the invention can be used to pulse operate high-pressure mercury-vapor lamps having ratings lower than 100 watts. Lamps with ratings of 25 watts or 50 watts could be efficiently operated in this manner and be used as practical light sources. The lamps can also contain additives such as thallium iodide, sodium iodide, etc. to further increase their efficiency in the manner well known to those skilled in the art.

We claim as our invention:

1. The method of operating a high-pressure gaseous discharge lamp that has a pair of spaced main electrodes, a predetermined wattage rating, and operates with a predetermined efficiency when energized by an alternating-current or a direct-current power source which supplied a power input to the lamp that corresponds to said wattage rating and thus constitutes the rated average power input for said lamp, which method comprises;

generating from 50 to 500 high-voltage pulses per second and applying said pulses to the main electrodes of said lamp, and

controlling the magnitude, the duration, and the repetition rate of said applied high-voltage pulses so that (a) the pulses have a duty cycle of from 5 percent to 25 percent and the instantaneous power input supplied to the lamp is greater than the rated average power input of said lamp but the average power input produced by said high-voltage pulses does not exceed said rated average power input, and (b) said lamp is thereby continuously operated solely by said applied high-voltage pulses at a power loading that increases the efficiency of the lamp without exceeding its wattage rating.

2. The method of claim 1 wherein;

the pulse repetition rate is within the range of about 60 to 110 pulses per second, and the duty cycle is approximately 20 percent.

3. The method of claim 1 wherein;

a keep-alive voltage of substantially constant magnitude is concurrently applied to the lamp electrodes, said high-voltage pulses are superimposed on said keep-alive voltage, and

said keep-alive voltage is of such magnitude that it constitutes from 3 percent to 20 percent of the rated average power input of said lamp.

4. The method of claim 1 wherein the magnitude of said applied high-voltage pulses is within a range of from 60 to 600 volts.

5. The method of claim 2 wherein;

said lamp comprises a high-pressure mercury-vapor discharge lamp having a rating of 100 watts, the magnitude of said applied high-voltage pulses is approximately 90 volts and approximately 9 amperes, the duration of said applied high-voltage pulses is 2 milliseconds, and

the repetition rate and duty cycle of said applied high-voltage pulses is 60 pulses per second and 12 percent, respectively, so that the instantaneous power input supplied to said lamp by said pulses is about 830 watts.

6. The method of claim 1 wherein;

said lamp comprises a high-pressure mercury-vapor discharge lamp having a rating of 100 watts, the magnitude of said applied high-voltage pulses is approximately 90 volts and approximately 5 amperes, the duration of said applied high-voltage pulses is 2 milliseconds, and

the repetition rate and duty cycle of said applied high-voltage pulses is about 110 pulses per second and 22 percent, respectively, so that the instantaneous power input supplied to said lamp by said pulses is about 460 watts.

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