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(54) **Energy-saving apparatus for dimming discharge lamps.**

(57) An apparatus for dimming discharge lamps with minimized power consumption comprises a phase control circuit connected to control the transfer of an A.C. power supply voltage to a combination of a discharge lamp such as a fluorescent lamp and ballast means, acting to transfer the power supply voltage to the lamp only during a portion of each half-cycle of that voltage in the region of the peak value thereof, and to block transfer of this voltage during the remainder of each half-cycle, together with a series resonance circuit which is connected such as to supply a constant low-level current to the lamp circuit during the half-cycle portions which are blocked by the phase circuit. A sufficiently high electrode temperature is thereby maintained to ensure reliable flicker-free operation over a wide range of control phase angles, without wasteful dissipation of energy in heating the lamp.

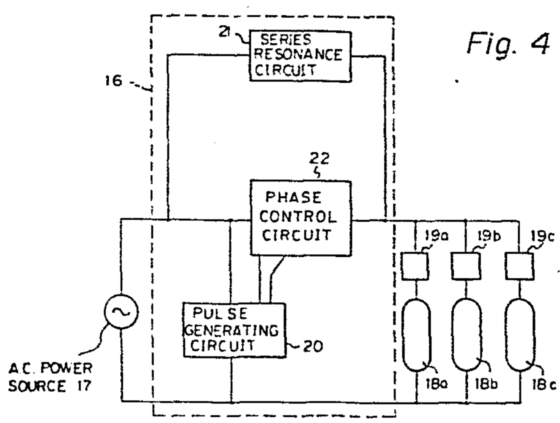

Fig. 4

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BACKGROUND OF THE INVENTION

The present invention relates to an apparatus for dimming discharge lamps, e.g. fluorescent lamps, by performing phase control of an A.C. power supply voltage, and in particular to such an apparatus whereby a high degree of stability of operation is ensured, with freedom from flickering or unreliable lighting of the lamp, together with substantially reduced energy consumption by comparison with prior art types of apparatus for dimming discharge lamps.

In the prior art, various means have been proposed for performing dimming of discharge lamps which are powered from an A.C. power supply voltage. In general, such prior methods employ phase control, whereby the A.C. power supply voltage is blocked from transfer to the discharge lamp during a certain proportion of each half-cycle of that voltage. Generally with such prior art methods, the power supply voltage is blocked during an initial portion θ of each half-cycle and is transferred to the discharge lamp during the remaining portion, from θ to 189°, of the half-cycle. However it has been found that with such prior art types of apparatus, if the magnitude of the blocking angle θ is 90° or more, i.e. if the conduction angle of the switching element

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used in the phase control circuit to perform blocking is made 0.5π radians or more, then ignition is not reliably established, resulting in flickering or failure of the lamp to turn on.

This problem is essentially due to the fact that a sufficiently high electrode temperature cannot be maintained with such a method, due to the complete blocking of current flow in the lamp during portions of each half-cycle of the power supply voltage. This problem is further aggravated for large values of phase angle, since if this angle exceeds 0.5π radians, then the peak value of the voltage waveform will not be applied across the lamp. As described in detail hereinafter, the starting voltage of a discharge lamp is strongly dependent on this electrode temperature, and if a sufficiently high temperature is not maintained, then the starting voltage will be excessively high, resulting in the problems of flickering and failure of the discharge lamp to light. To overcome this problem, it has been proposed to provide an auxiliary power supply circuit to pass a preheating current through the discharge lamp during each of the intervals in which the power supply voltage is blocked by the phase control circuit. The voltage for producing this low level of current would be set to approximately one-half of the power supply voltage. Thus, an additional transformer, with the necessary wiring etc would be required, in addition to the step-up transformer which is normally necessary for operation of such a discharge lamp. Such an arrangement would add substantially to the overall cost of a discharge lamp installation, and is therefore undesirable.

Another method which has been proposed to overcome the problem described above is to provide means for producing voltage pulses, to be applied accross the discharge lamp during each portion of a power supply voltage half-cycle which is blocked by the phase control circuit. Such pulses would be timed such as to effectively maintain a continuous flow of low-level current through the discharge lamp at all times. However, such a system would necessitate separate complex circuit means for producing the necessary voltage pulses, with precise timing of the pulses, i.e. with each pulse being generated at a point in time close to the start of each blocking portion of a half-cycle.

There is therefore a requirement for an apparatus for dimming discharge lamps whereby the disadvantages of prior art methods described above would be eliminated, and whereby reliable flicker-free operation of the lamp would be ensured with a minimum of additional circuitry being required. Such an apparatus is disclosed by the present invention, and has the additional advantage of enabling a substantial reduction in energy consumption of the discharge lamp.

SUMMARY OF THE INVENTION

According to the present invention, there is provided an apparatus for dimming a discharge lamp, adapted to be coupled between a source of an A.C. power supply voltage and a combination of a discharge lamp with ballast means, said apparatus comprising: phase control circuit means for applying said power supply voltage to said discharge lamp and ballast means during conduction intervals each corresponding to a predetermined central portion of a half-cycle of said power supply voltage, and for blocking transfer of said power supply voltage to said discharge lamp and ballast means during the remaining portions of said half-cycle which precede and succeed said central portion, and; a series resonance circuit coupled in parallel with said phase control circuit means between said power supply voltage source and said discharge lamp and ballast means, comprising an inductor and a capacitor, with the values of inductance and capacitance thereof being selected such as to pass a substantially constant preheating current through said discharge lamp and ballast means during each half-cycle of said power supply voltage including said portions thereof in which blocking by said phase control circuit means occurs, said preheating current level being substantially lower than the maximum current which flows in said discharge lamp and ballast means during said conduction intervals.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing the relationships between supply voltage level and the lamp voltage, luminous flux, lamp current and lamp power characteristics of a fluorescent lamp;

Fig. 2 is a graph to illustrate the relationship between electrode temperature, preheating current and starting voltage of a 40W 100V fluorescent lamp;

Fig. 3 is a set of graphs illustrating the relationship between ignition phase angle and luminous flux for two prior art methods of phase control of a discharge lamp and for the method of the present invention;

Fig. 4 is a general block diagram to illustrate the basic elements of an apparatus for dimming discharge lamps according to the present invention;

Fig. 5 is a waveform diagram to illustrate the operation of an apparatus for dimming discharge lamps according to the present invention;

Fig. 6 is a general circuit diagram of an embodiment of an apparatus for dimming discharge lamps according to the present invention;

Fig. 7 and Fig. 8 are circuit diagrams of a full-wave rectifier circuit and a Schmitt trigger circuit used in the embodiment of Fig. 6;

Fig. 9 is a waveform diagram for illustrating the operation of the embodiment of Fig. 6;and,

Fig. 10 is a set of graphs showing the relationship between ignition phase angle and power consumption for an apparatus for dimming discharge lamps according to the present invention and for two prior art types of lamp dimming apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to Fig. 1, the relationships are shown between the supply voltage applied to a fluorescent lamp circuit (comprising stabilizer means connected in series with a fluorescent lamp) and the characteristic curves for lamp voltage (i.e. the voltage which appears across the lamp itself), the lamp current, the lamp power (i.e. the power consumed to operate the lamp) and the luminous flux produced. As shown, an increase in the lamp current, resulting from an increase in the supply voltage, will cause a reduction in the lamp voltage, that is to say such a fluorescent lamp displays a negative resistance characteristic while in operation. For this reason, it is necessary to provide suitable ballast means, such as an inductor connected in series with the lamp, in order to ensure stable operation.

To start operation of a fluorescent lamp, the electrode temperature is raised by passing current

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through lamp filaments, while a suitably high voltage is applied across the lamp. The value of this voltage is substantially higher than the voltage which develops across the fluorescent lamp after ignition, i.e. after the lmap attains a low-impedance state.

After the required temperature has initially been attained, by this filament heating, the voltage level required to start ignition of the lamp (referred to in the following as the starting voltage) becomes sufficiently low that the lamp begins operation. That is to say, when a point is reached during each half-cycle of the AC voltage applied across the lamp at which the instantaneous value of the AC voltage exceeds the starting voltage, then the lamp begins to generate illumination. Subsequently during that half-cycle when instantaneous value of the applied voltage falls below the starting voltage, level, the lamp turns off. With a conventional type of fluorescent lamp installation (i.e. one which does not incorporate a phase-control dimming apparatus), the required high lamp temperature to ensure a suitably low starting voltage is maintained by the current passing through the lamp during operation thereof. As described above, the lamp is in effect extinguished at a point towards the end of each half-cycle of the power supply voltage waveform, and is restarted at some point in the next half-cycle of that waveform, when the instantaneous voltage applied to the lamp reaches the requisite starting voltage level. So long as a suitably high lamp temperature is maintained, then this process will be repetitively performed at a sufficiently high rate (e.g. 100 times per second with a 50 Hz supply voltage) that no visible flicker will appear. However if the lamp temperature should not be maintained at the requisite level, then the required starting voltage will increase, thereby necessitating repetition of the initial ignition procedure, resulting in lamp flicker or temporary failure of illumination.

Table 1 below shows the relationship between the phase angle, average value and instantaneous value of voltage of a supply having a sinusoidal waveform of the form 100 sin ω t (V).

Table I

Electrical angle (π radian)	Average voltage (V)	Instantaneous voltage (V)
0	0	0
0.05	15.6	22.1
0.1	30.9	43.7
0.15	45.4	64.2
0.2	58.8	83.1
0.25	70.7	100
0.3	80.9	114.4
0.35	89.1	126
0.4	95.1	134.5
0.45	98.8	139.7
0.5	100	141.4
0.55	98.8	139.7
0.6	95.1	134.5
0.65	89.1	126
0.7	80.9	114.4
0.75	70.7	100
0.8	58.8	83.1
0.85	45.4	64.2
0.9	30.9	43.7
0.95	15.6	22.1
1.	0	0

Taking the example of a typical 100 V 40 W fluorescent lamp, it is found that after ignition has been initially established as described above, by filament current preheating, then the starting voltage required is approximately 170 V. With the generally employed step-up transformer ratio used for such a flurescent lamp, the corresponding primary voltage (i.e. supply voltage) value is approximately 126 V. That is to say, the lamp will turn on when an instantaneous supply voltage levelof 126 V is reached during each half-cyle of the supply voltage, i.e. at a phase angle of 0.35π radians as shown in Table 1 above, and will turn off when the instantaneous supply voltage falls below 126 V at a later point in the half-cycle, i.e. at a phase angle of 0.65π radians.

If however the electrode temperature of the lamp should fall below a certain level during operation, then the necessary starting voltage will increase, e.g. typically to 270 V for this 100 V 40 W example. This corresponds to an instantaneous primary, e.g. supply voltage level of about 169 V. Since this value is not attained by the power supply voltage, the lamp would go out, and the filament heating start-up procedure would have to be initiated. It can thus be understood that for reliable and flicker-free operation of a fluorescent lamp, it is necessary to maintain a suitable electrode temperature.

The relationship between electrode temperature and starting voltage for the 100 V 40 W fluorescent lamp example discussed above, and also the necessary preheating current, are shown in the graph of Fig. 2. As can be seen, the necessary starting voltage increases very rapidly, from about 170 V to 270 V, as the electrode temperature falls below approximately 700° C, corresponding to a preheating current which is slightly higher than 0.3 A. An increase in electrode temperature beyond this value does not result in any change in the starting voltage. With a conventional type of apparatus for driving a fluorescent lamp, i.e. one which does not employ phase control, a sufficiently high electrode temperature is maintained after initial start-up, so that continuous flicker-free operation of the lamp is obtained. However in practice, more power is expended in heating the lamp while it is in operation than is actually required to maintain the minimum necessary electrode temperature for reliable flicker-free operation. That is to say, if the starting voltage of the 40 W 100 V fluorescent lamp of the above example is 170 V after the required temperature has been established, then the initial part of each half-cycle of the drive voltage, until the 170 V level is reached, will represent a substantial amount of wasted energy, which produces excessive heating of the lamp and no illumination output. Similarly, energy is wasted during the latter portion of each half-cycle, i.e. after the instantaneous voltage applied to the lamp falls below 170 V. Thus, illumination is only produced by the part of each half-cycle lying between these two points. For this 110V 40 W lamp example, this starting voltage of 170 V approximately corresponds to an average primary voltage (i.e. power supply voltage) value of 90V. As shown in Table 1, this corresponds to phase angles of 0.35 and 0.65π radians approximately, and an instantaneous voltage level of 126V. Thus, power is wasted during the portion of each half-cycle of the power supply voltage which is outside the range from 0.35π to 0.65π radians, that is to say the lamp is only illuminated while the power supply voltage is within that range.

In the prior art, proposals have been made to eliminate this waste of energy, by utilizing phase control circuit means to block the application of the power supply voltage to the fluorescent lamp during those initial and final portions of each half-cycle which do not contribute to illumination output. However it has been found that serious problems arise with such prior art arrangements, with regard to flickering of the lamp and unreliability of lighting operation. This is basically due to the fact that, as explained above, it is necessary to maintain a sufficiently high electrode temperature while the lamp is in operation, in order to ensure that the starting voltage is held at a suitably low value. However with such prior art drive systems, since no current flows through the fluorescent lamp during each of the blocking intervals, a sufficiently high electrode temperature cannot be maintained. A rise in starting voltage occurs therefore, resulting in the drive voltage being only marginally sufficient, or too low. This produces flickering, or causes the lamp to be extinguished, whereupon the starting procedure to raise the electrode temperature by filament heating will be automatically initiated in a repetitive manner.

With the present invention, these problems are eliminated by ensuring that a current is passed continuously through the fluorescent lamp during each of the intervals in which application of the supply voltage is blocked, i.e. during the initial and latter portions of each half-cycle of the power supply voltage. The current thus caused to flow is held at a predetermined low level, which is sufficient to ensure that a suitable electrode temperature is maintained during operation of the lamp. It is found that a substantial saving in energy consuption can be achieved in this way, while reliable flicker-free operation of the lamp is attained. It is an important feature of the present invention that the means for producing this low-level current flow are extremely simple, comprising only a series resonance circuit formed of an inductor and a capacitor.

Fig. 3 shows the relationship between relative luminous flux and ignition phase angle for two prior art methods of phase control and for the method of the present invention. In the following, the term "ignition phase angle" will be used to designate the portion of each half-cycle of the power supply voltage (expressed in radians) which is blocked from transfer to the fluorescent lamp by the phase control circuit. Numeral 10 denotes the characteristic for a first prior art phase control apparatus, whereby the power supply voltage is completely blocked from transfer to the fluorescent lamp during an ignition phase angle in the initial part of each half-cycle, as illustrated by half-cycle 11. As described hereinabove, such a method has the disadvantage of failure to maintain a sufficiently high electrode temperature of the fluorescent lamp during operation. In addition, as the ignition phase angle is increased above about 0.4π radians, a sudden drop in illumination output occurs, and for greater values of ignition phase angle the lamp will cease operation. This is due to the fact that at such large phase angles, the initial instantaneous voltage level applied to the lamp during each half-cycle is close to the peak value of the voltage waveform, which may fluctuate due to ripple or interference in the power supply voltage. This fact, combined with the increased starting voltage caused by the low electrode temperature of the lamp will result in reduced light output and flickering. Any increase in the ignition phase angle beyond 0.5π radians will of course result in a reduction of the maximum voltage applied to the lamp below the peak value of the waveform, resulting in failure of the lamp to operate.

Numeral 12 denotes the illumination/ignition phase angle characteristic for a second prior art method of phase angle control for dimming a fluorescent lamp, with the corresponding half-cycle waveform 13. In this method, the power supply voltage is blocked from transfer to the fluorescent lamp during a first portion P1 and also during a second portion P2 of the power supply voltage half-cycle. Thus, voltage is only applied to the lamp during the hatched-line portion of each half-cycle, i.e. during the portion in which the applied voltage will result in an illumination output. As shown by characteristic 12, this method provides gradual control of illumination over a wider range of ignition phase angles than is possible with the first method described above. However, since no current is passed through the lamp during the blocking portions P1 and P2 of each half-cycle, a sufficiently high electrode temperature cannot be maintained, for large values of ignition phase angle, while the lamp is in operation. This will lead to unreliability of operation and flickering due to increases in the starting voltage required, for the reasons described above, so that such a fluorescent lamp dimming method has not been put into practical application.

Curve 14 shows the illumination/ignition phase angle characteristic for the fluorescent lamp dimming method used with the present invention, and numeral 15 denotes the corresponding half-cycle waveform. As indicated, the power supply voltage is blocked from application to the lamp during an initial portion P1 and a latter portion P2 of each half-cycle, as for the second prior art method described above. However a low-level current of fixed value, which will be referred to simply as the preheating current, is passed through the lamp during each of these blocking intervals P1 and P2, as indicated by the hatched portions for each of these intervals in waveform 15. As a result of this preheating current flow, a sufficiently high lamp temperature is maintained to ensure no increase in the starting voltage level, as discussed above with reference to Fig. 2. This fact enables reliable, flicker-free operation, with smooth and continuous control of the illumination level over a wide range of ignition phase angles, as illustrated by curve 14.

Although an apparatus according to the present invention has been referred to in the above as a dimming apparatus, it will be apparent from characteristic 14 in Fig. 3 that it can also be considered as a power-saving apparatus. That is to say, only a relatively minor change takes place in the illumination output of the fluorescent lamp as the ignition phase angle is increased to a value of the order of 0.6π radians. Thus, even if the ignition phase angle is held fixed at such a value, or an even greater value, with no variable dimming function being provided, a very substantial reduction in the energy consumed by the lamp operation will be attained. As described above, this is due to the fact that no energy is expended in unnecessary heating of the lamp above the optimum temperature required to minimize the starting voltage value.

The amount of energy wasted in a conventional fluorescent lamp which does not utilize a phase control apparatus can be estimated as follows.

Assuming that the lamp does not light during each half-cycle of the power supply voltage until a phase angle of 0.35π radians, then the proportion of power dissipated during this initial portion of the half-cycle is given as:

$$(1 - \cos 0.35\pi \text{ radians})/2 \doteqdot 0.273$$

That is to say, approximately 27% of the total power consumed by the lamp is dissipated in this initial portion of each half-cycle. Furthermore, assuming that the lamp is extinguished during each half-cycle when a phase angle of 0.8π radians is reached, then the proportion of the total power consumed from that point until the end of the half-cycle is given as:

$$(1 + \cos 0.8\pi \text{ radians})/2 \doteqdot 0.0954$$

This means that approximately 10% of the total power is dissipated in this latter portion of each half-cycle, so that the amount of power consumed during the times in which the lamp is producing no illumination is approximately 37% of the total power supplied to the lamp. This is much more than is actually required (in conjunction with the power dissipated as heat during each portion of a half-cycle in which the lamp is producing illumination) to maintain a sufficiently high electrode temperature, and a substantial part of this wasted energy is effectively saved by an apparatus according to the present invention.

Fig. 4 is a general block diagram to illustrate the essential features of an apparatus for dimming discharge lamps according to the present invention, which comprises the components shown within broken-line outline 16. Numeral 17 denotes a source of A.C. power supply voltage, while numeral 18a denotes a discharge lamp, which is connected in series with ballast and transformer means 19a comprising means for stepping up the power supply voltage from source 17 to a sufficiently high level to operate discharge lamp 18a if necessary, together with ballast means to stabilize the lamp operation. A plurality of other sets of discharge lamps and ballast and transformer means may be connected in parallel with the first set, i.e. as designated 18b, 19b and 18c, 19c in Fig. 4. For brevity of description, the discharge lamps will be collectively referred to by numeral 17, and their ballast and transformer means by numeral 19. Numeral 22 denotes a phase control circuit which is connected between power supply voltage source 17 and discharge lamp 18, and which includes electronic switch means for selectively blocking and transferring the power supply voltage to discharge lamp 19. This selective blocking is performed as illustrated by waveform 15 in Fig. 3, i.e. so that the power supply voltage is only transferred to the discharge lamp during a central portion P3 of each half-cycle which is substantially symmetrically disposed with respect to the peak voltage of the power supply voltage.

Numeral 21 denotes a series resonance circuit which serves as a current-limiting source of a low-level preheating current which is substantially constant at a predetermined value, and which flows both during the blocking intervals P1 and P2 in waveform 15 of Fig. 3 and also during the conducting interval P3, of each half-cycle of the power supply voltage, to thereby ensure substantially continuous current flow through the discharge lamp and thereby maintain the requisite electrode temperature as described above. This series resonance circuit 21 is arranged such that the output (no-load) voltage produced is substantially equal to the power supply voltage, and that the output voltage and current are substantially in phase with one another.

The operation of phase control circuit 22 is controlled by signals applied from a pulse generating circuit 20, which preferably includes externally

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operable means for varying the ignition phase angle set by phase control circuit 22, to thereby vary the level of illumination of discharge lamp 19 as required.

The operation of such an apparatus is illustrated by the waveform diagrams of Fig. 5(a) to (e). Fig. 4(a) shows the waveform of the power supply voltage from source 17. In response to signals from pulse generating circuit 20, phase control circuit 22 transfers the power supply voltage to discharge lamp 18 (via ballast and transformer means 19) during a portion of each half-cycle of the power supply voltage waveform from T1 to T2, as shown in Fig. 5(b). The resultant waveform of current flow into discharge lamp 18 is shown in Fig. 5(d). At the same time, a preheating current having the waveform shown in Fig. 5(c) flows through discharge lamp 18, resulting from the output voltage from series resonance circuit 21, this current having a fixed maximum level and being in phase with the power supply voltage as shown. As a result, the total current flow in discharge lamp 18 has the composite waveform shown in Fig. 4(e).

Referring now to Fig. 6, a more detailed circuit diagram of an embodiment of the present invention is shown, having the basic configuration shown in Fig. 4.

The series resonance circuit 21 comprises a capacitor 52 and inductor 54, with the values of these components being selected (and with the inductance of inductor 54 being adjustable, if necessary) such as to provide the required level of preheating current flow. Inductor 54 may comprise a saturable reactor, however this is not an essential requirement. The phase control circuit 22 comprises an electronic switch comprising a diode bridge circuit made up of diodes 22 to 30, combined with a transistor 34. A capacitor 40 and resistor 42 provide protection for transistor 34. Numeral 32 denotes a saturable reactor which is incorporated to smooth out any voltage transients which may enter from the power source 17 or are generated by the switching action of transistor 34. Such means for eliminating or attenuating voltage transients have been found to greatly enhance the reliability of operation of such an apparatus, and may comprise other components than a saturable reactor, e.g. an inductance-capacitance filter.

The pulse generating circuit 18 comprises a full-wave rectifier circuit 44, for rectifying the power supply voltage. The resultant output, having the waveform shown in Fig. 9(a), is applied to a level detection circuit 46 having a low degree of level sensing hysteresis, such as a suitably adjusted Schmitt trigger circuit. Such a Schmitt circuit is illustrated in Fig. 8, while a suitable full-wave rectifier circuit is shown in Fig. 7. Control pulses thereby produced from level detection circuit, as shown in Fig. 9(b), are input to a pulse amplifier circuit 48. As shown, each of these pulses is substantially symmetrically arranged with respect to the peak value of the power supply voltage, i.e. corresponds to portion P3 of each half-cycle as described hereinabove with reference to Fig. 3. The width of these pulses, which determines the magnitude of the ignition phase angle and hence the illumination level provided by discharge lamp 18, can be controlled by actuation of an external operating member coupled to a potentiometer 47 provided in level detection circuit 46 to vary the detection threshold level.

The control pulses from amplifier 48 are applied to the base of transistor 34, so that the power supply voltage is transferred to discharge lamp 19 only during each portion P3 of a half-cycle in which a control pulse is applied from pulse generating circuit 20 to the base of transistor 34, thereby rendering transistor 34 conductive.

It will be apparent that this embodiment may be modified in various ways, e.g other types of electronic switch may be utilized, other types of level detection circuit, etc.

Fig. 10 illustrates the relationship between power consumed and ignition phase angle, for an apparatus according to the present invention, as illustrated by curve 58, and for the first and second prior art phase control methods described previously, as illustrated by curves 60 and 62 respectively. It can be seen from these that a substantial reduction in power consumption can be attained by an apparatus according to the present invention, and that this reduction is increasingly significant as the ignition phase angle is increased.

It can be understood from the above description that an apparatus for dimming discharge lamps according to the present invention can have a simple and easily manufactured circuit configuration, and can be connected directly to an existing discharge lamp installation without modification to any existing ballast or transformer means in that installation. In addition to enabling a greater range of control of lamp illumination with reliable flicker-free operation than is possible with prior art methods, an apparatus according to the present invention also provides a significant reduction in the energy consumption of the discharge lamp.

Although the present invention has been described in the above with reference to specific embodiments, it should be noted that various changes and modifications to the embodiments may be envisaged, which fall within the scope claimed for the invention as set out in the appended claims. The above specification should therefore be interpreted in a descriptive and not in a limiting sense.

Although in the above embodiment the power supply voltage is transferred continuously to the discharge lamp during interval P3, it is equally possible to perform periodic interruption, i.e. chopping of the transfer of the power supply voltage during each interval P3, as is known in the prior art. This will not alter the important concepts of the present invention.

CLAIMS

1. An apparatus for dimming a discharge lamp, adapted to be coupled between a source of an A.C. power supply voltage and a combination of a discharge lamp with ballast means, said apparatus comprising:

phase control circuit means for applying said power supply voltage to said discharge lamp and ballast means during conduction intervals each corresponding to a predetermined central portion of a half-cycle of said power supply voltage, and for blocking transfer of said power supply voltage to said discharge lamp and ballast means during the remaining portions of said half-cycle which precede and succeed said central portion, and;

a series resonance circuit coupled in parallel with said phase control circuit means between said power supply voltage source and said discharge lamp and ballast means, comprising an inductor and a capacitor, with the values of inductance and capacitance thereof being selected such as to pass a substantially constant preheating current through said discharge lamp and ballast means during each half-cycle of said power supply voltage including said portions thereof in which blocking by said phase control circuit means occurs, said preheating current level being substantially lower than the maximum current which flows in said discharge lamp and ballast means during said conduction intervals.

2. An apparatus for dimming a discharge lamp according to claim 1, in which said phase control circuit means comprise a phase control circuit including a electronic switch means for controlling the application of said power supply voltage to said discharge lamp, and a pulse generating circuit for generating control pulses to enable conduction by said electronic switch means, the width of said control pulses thereby determining the width of said conduction intervals.

3. An apparatus for dimming a discharge lamp according to claim 2, in which said pulse generating circuit comprises a full-wave rectifier circuit coupled to said power supply voltage source for producing a rectified full-wave voltage therefrom, and a level detection circuit for initiating and terminating each of said control pulses when said full wave voltage waveform exceeds and falls below a predetermined level, respectively.

4. An apparatus for dimming a discharge lamp according to claim 3, and further comprising externally operable means coupled to said level

detection circuit for controlling the detection level thereof, to thereby control the duration of each of said control pulses and thereby control the width of said conduction intervals and hence the illumination level of said discharge lamp.

Fig. 1

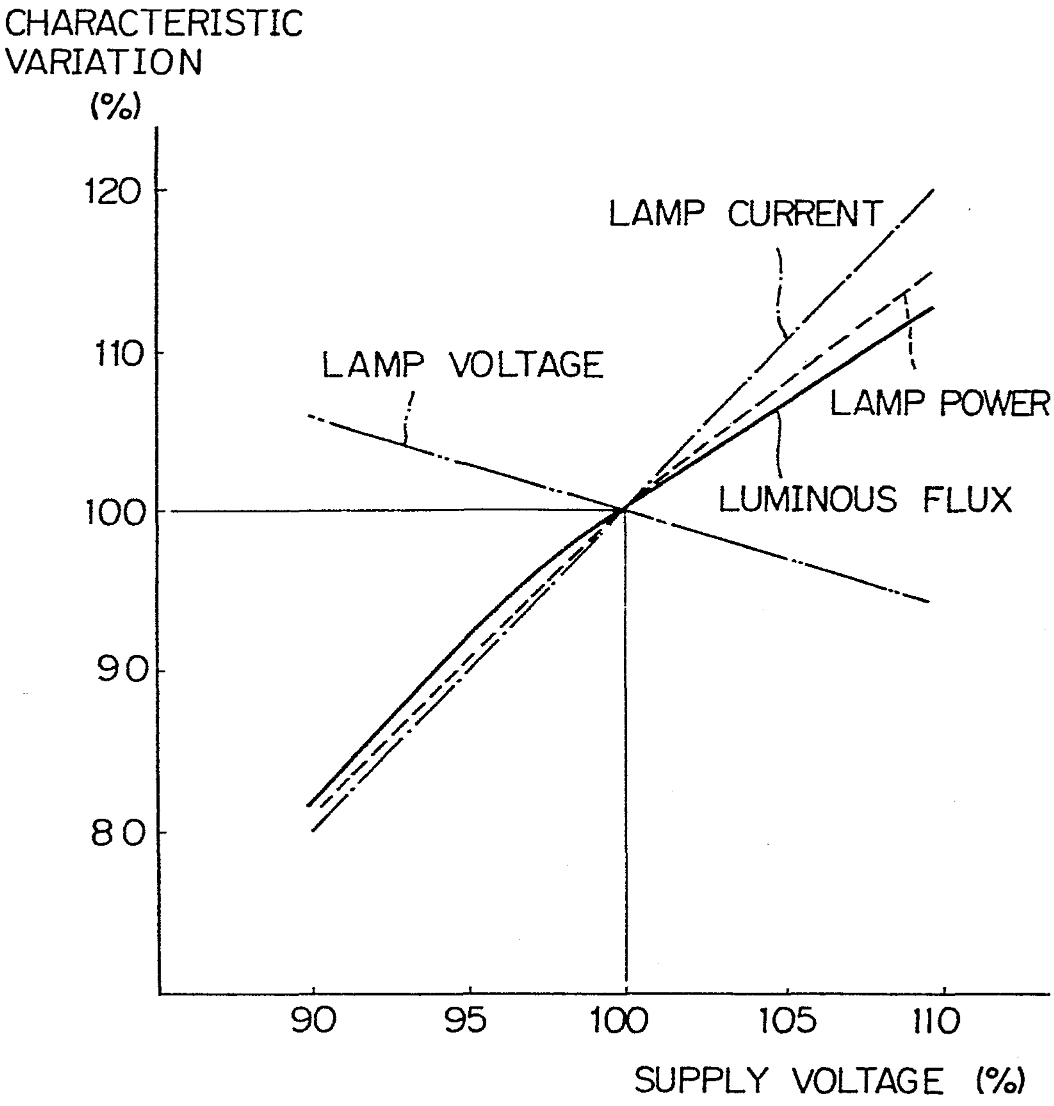

CHARACTERISTIC VARIATION (%)
120
110
100
90
80
LAMP CURRENT
LAMP VOLTAGE
LAMP POWER
LUMINOUS FLUX
90
95
100
105
110
SUPPLY VOLTAGE (%)

Fig. 2

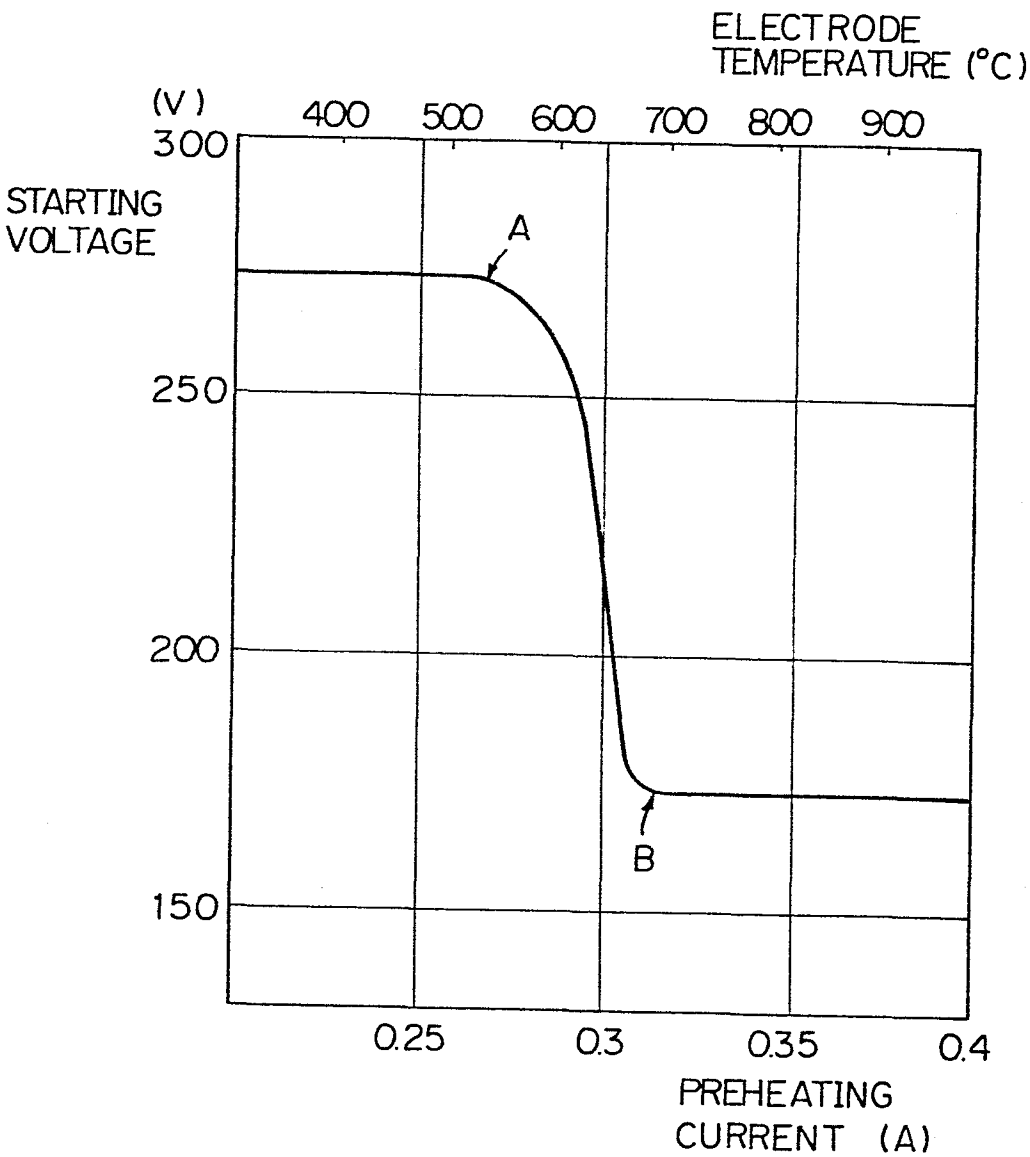

ELECTRODE
TEMPERATURE (°C)
(V)
400
500
600
700
800
900
300
STARTING
VOLTAGE
A
250
200
B
150
0.25
0.3
0.35
0.4
PREHEATING
CURRENT (A)

Fig. 3

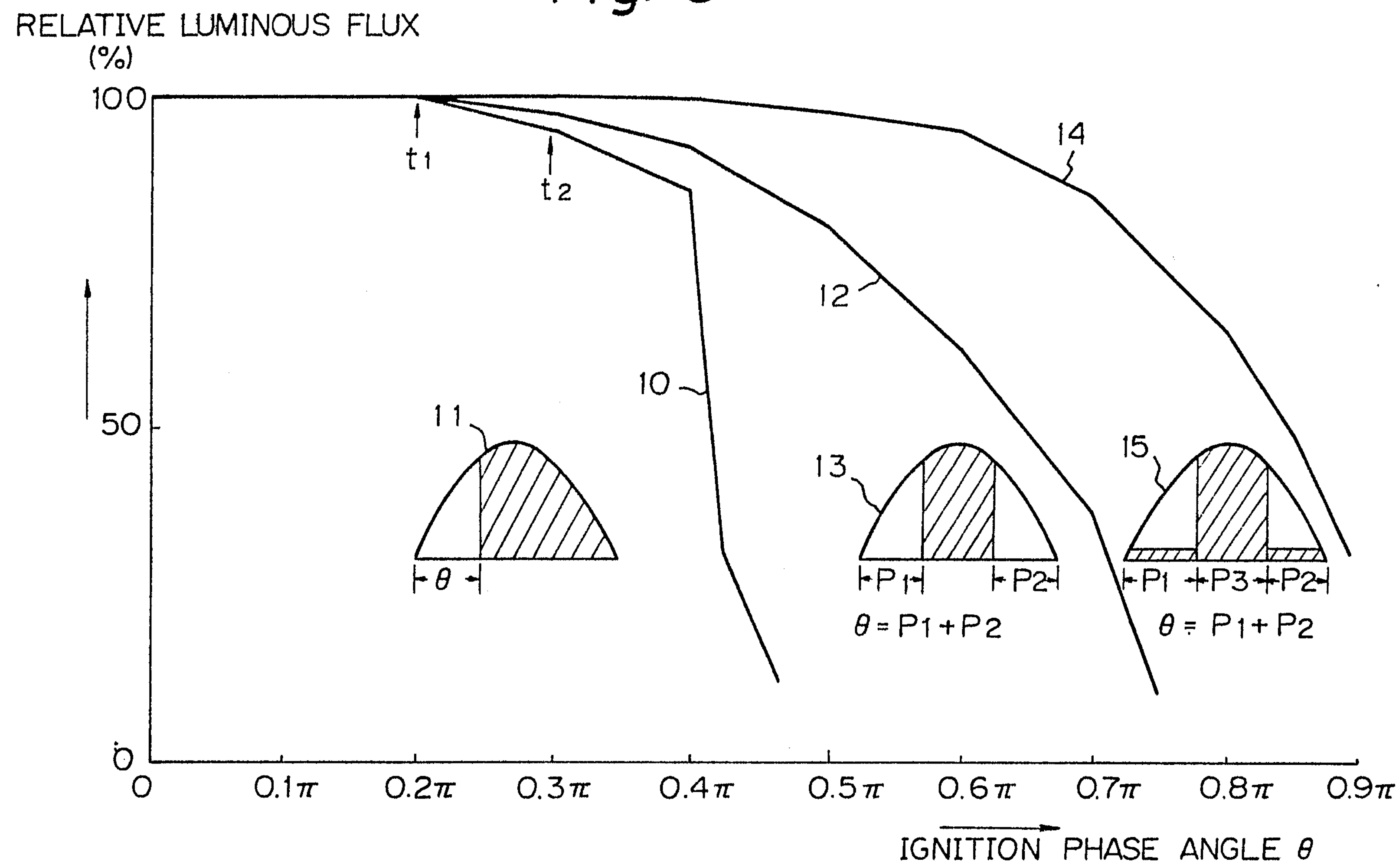

RELATIVE LUMINOUS FLUX
(%)
100
50
0
0
0.1π
0.2π
0.3π
0.4π
0.5π
0.6π
0.7π
0.8π
0.9π
IGNITION PHASE ANGLE θ
t1
t2
10
11
12
13
14
15
θ
P1
P2
P3
θ = P1 + P2
θ ≑ P1 + P2

Fig. 4

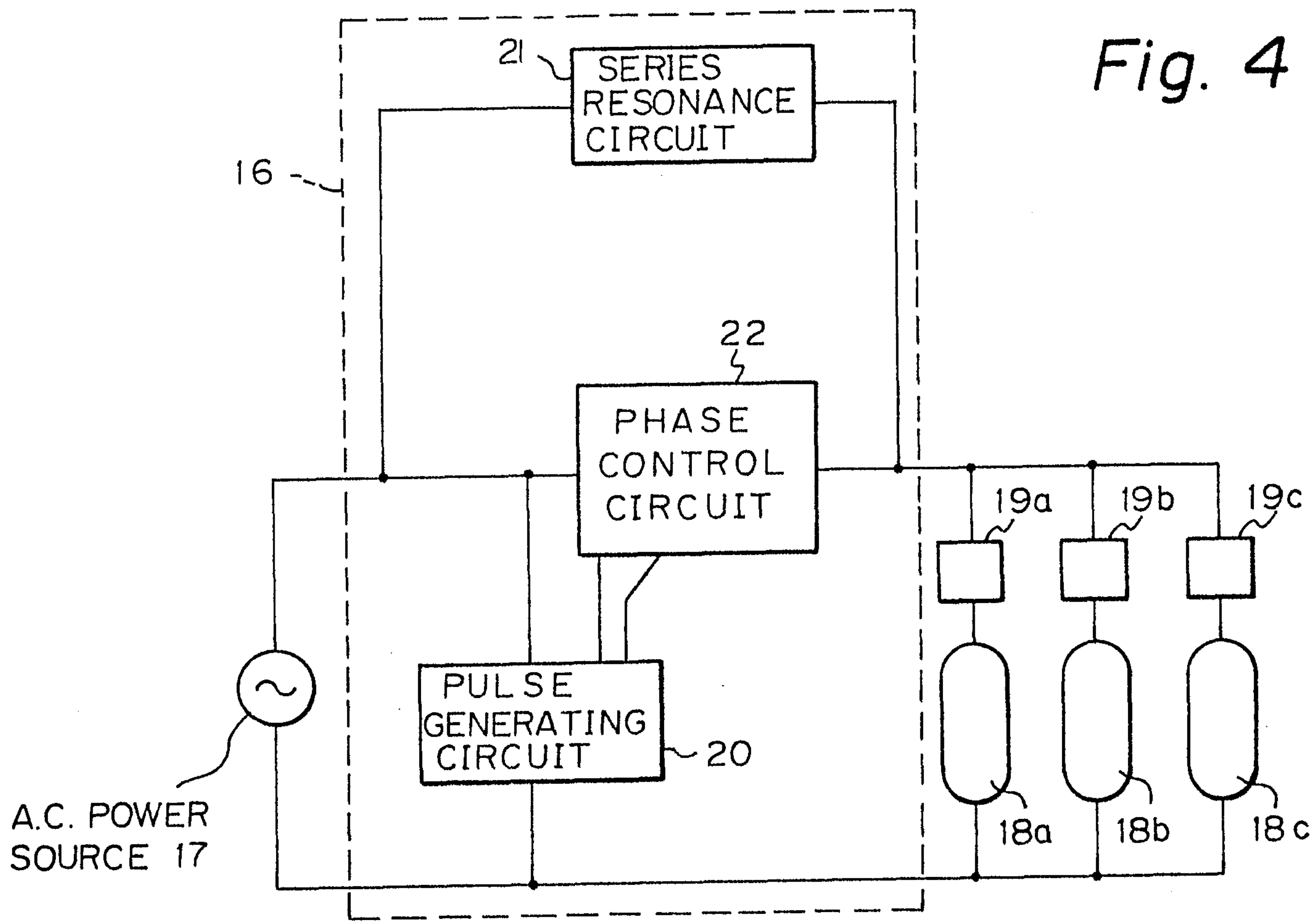

16
21
SERIES RESONANCE CIRCUIT
22
PHASE CONTROL CIRCUIT
PULSE GENERATING CIRCUIT
20
A.C. POWER SOURCE 17
19a
19b
19c
18a
18b
18c

Fig. 5

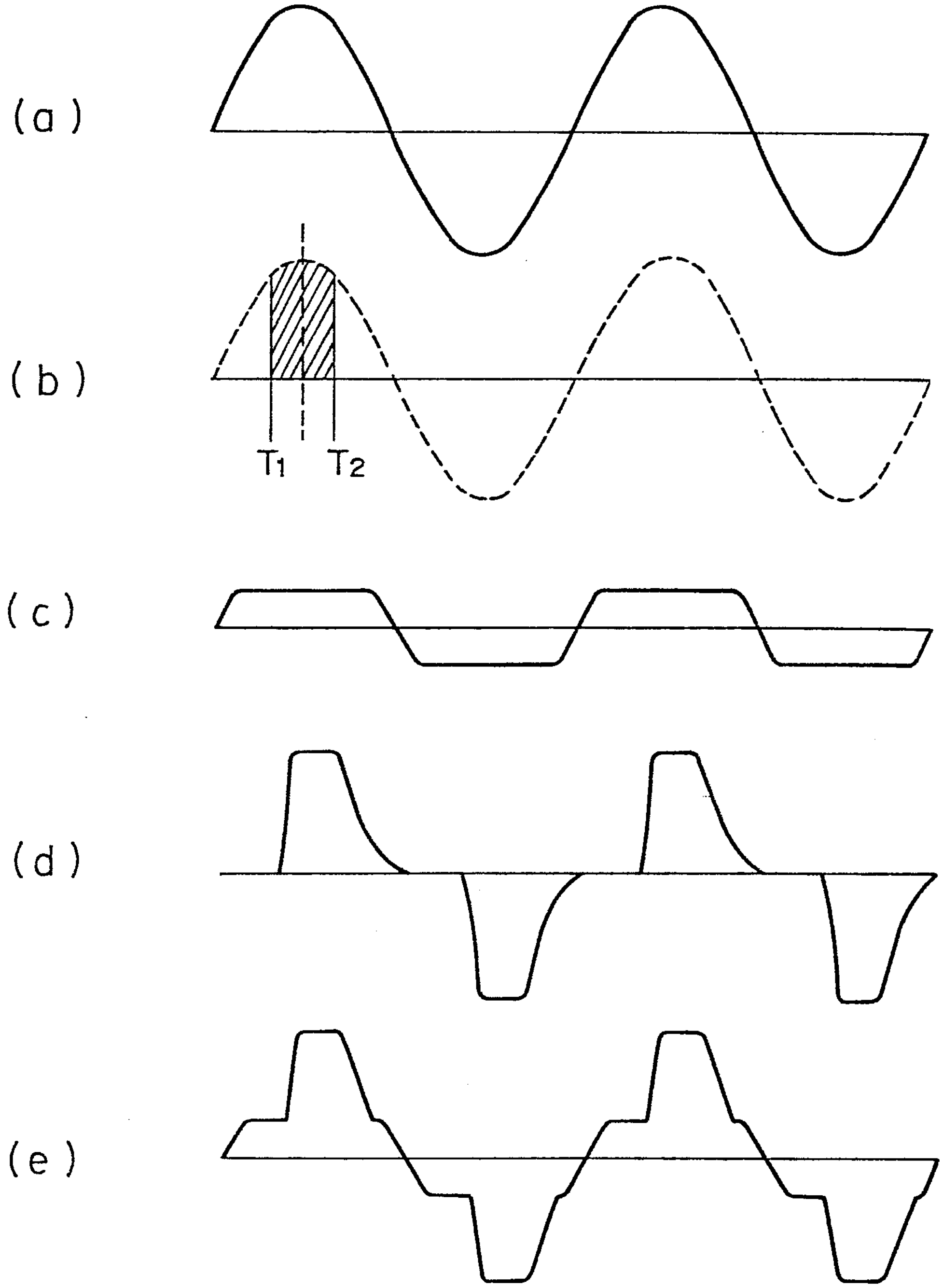


Fig. 6

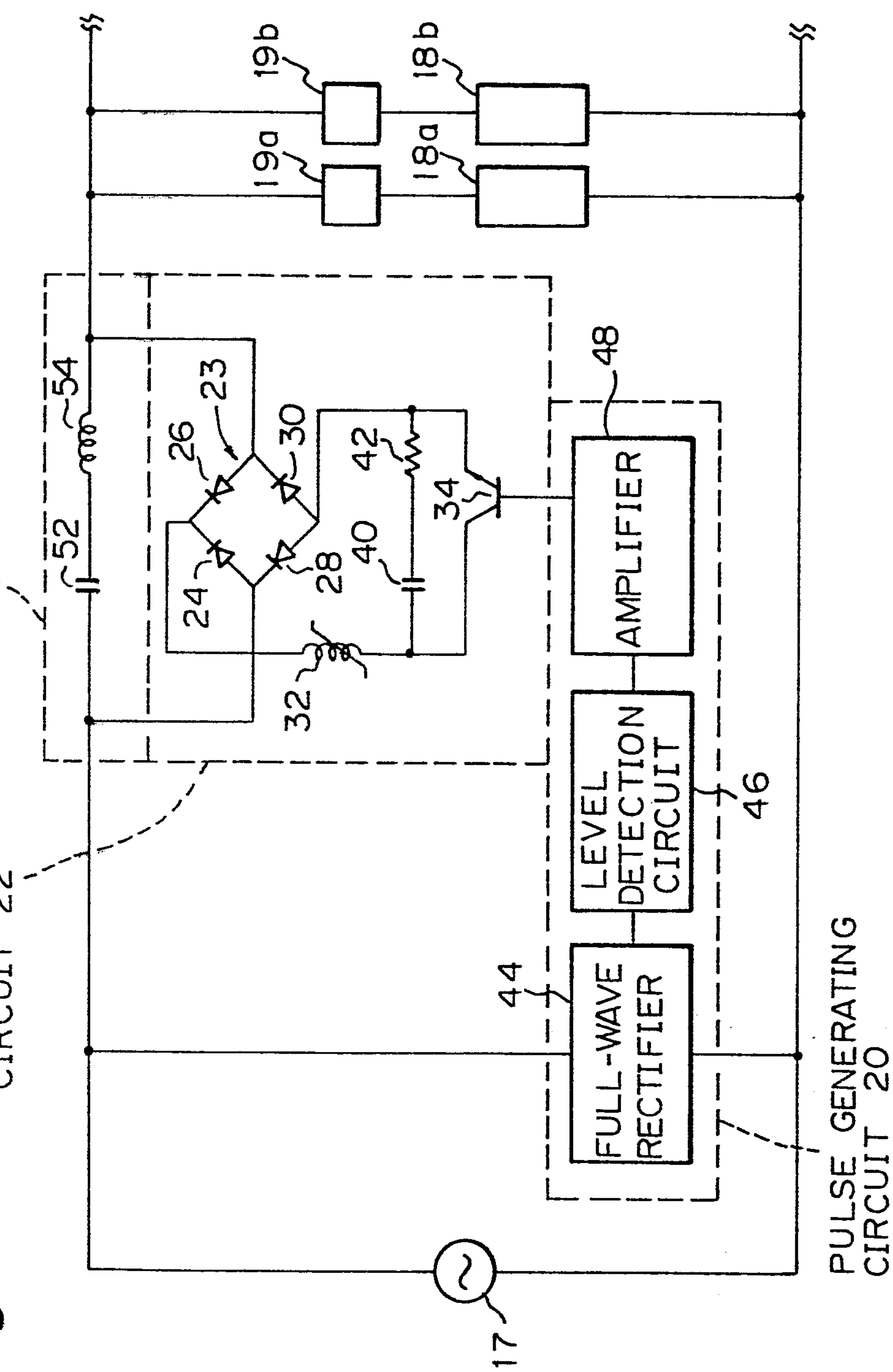

SERIES RESONANCE
CIRCUIT 21
PHASE CONTROL
CIRCUIT 22
PULSE GENERATING
CIRCUIT 20
FULL-WAVE
RECTIFIER
LEVEL
DETECTION
CIRCUIT
AMPLIFIER
17
18a
18b
19a
19b
23
24
26
28
30
32
34
40
42
44
46
48
52
54

Fig. 7

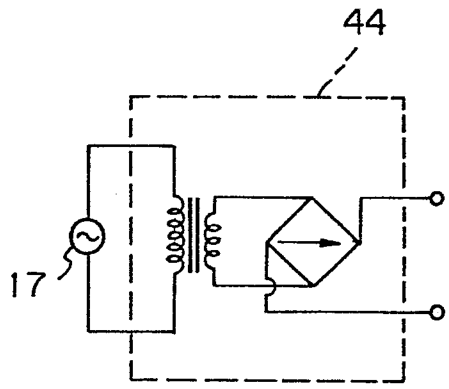


Fig. 8

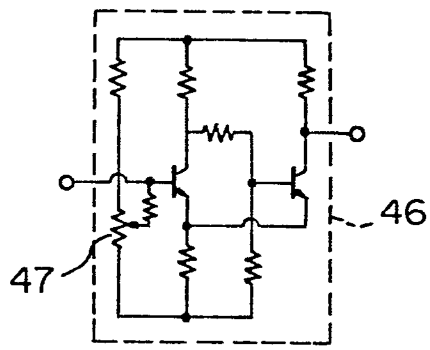


Fig. 9

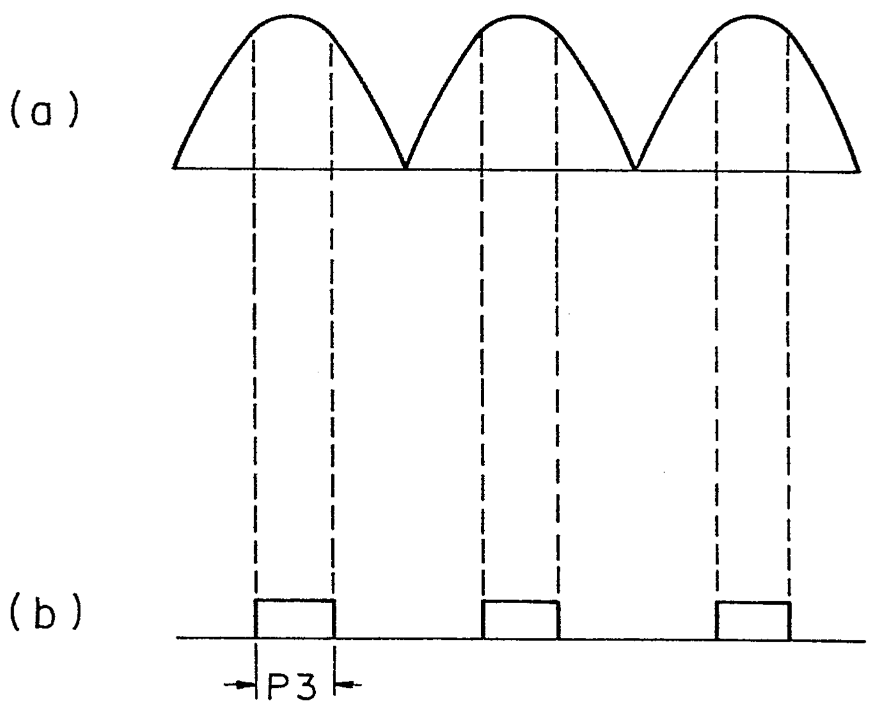
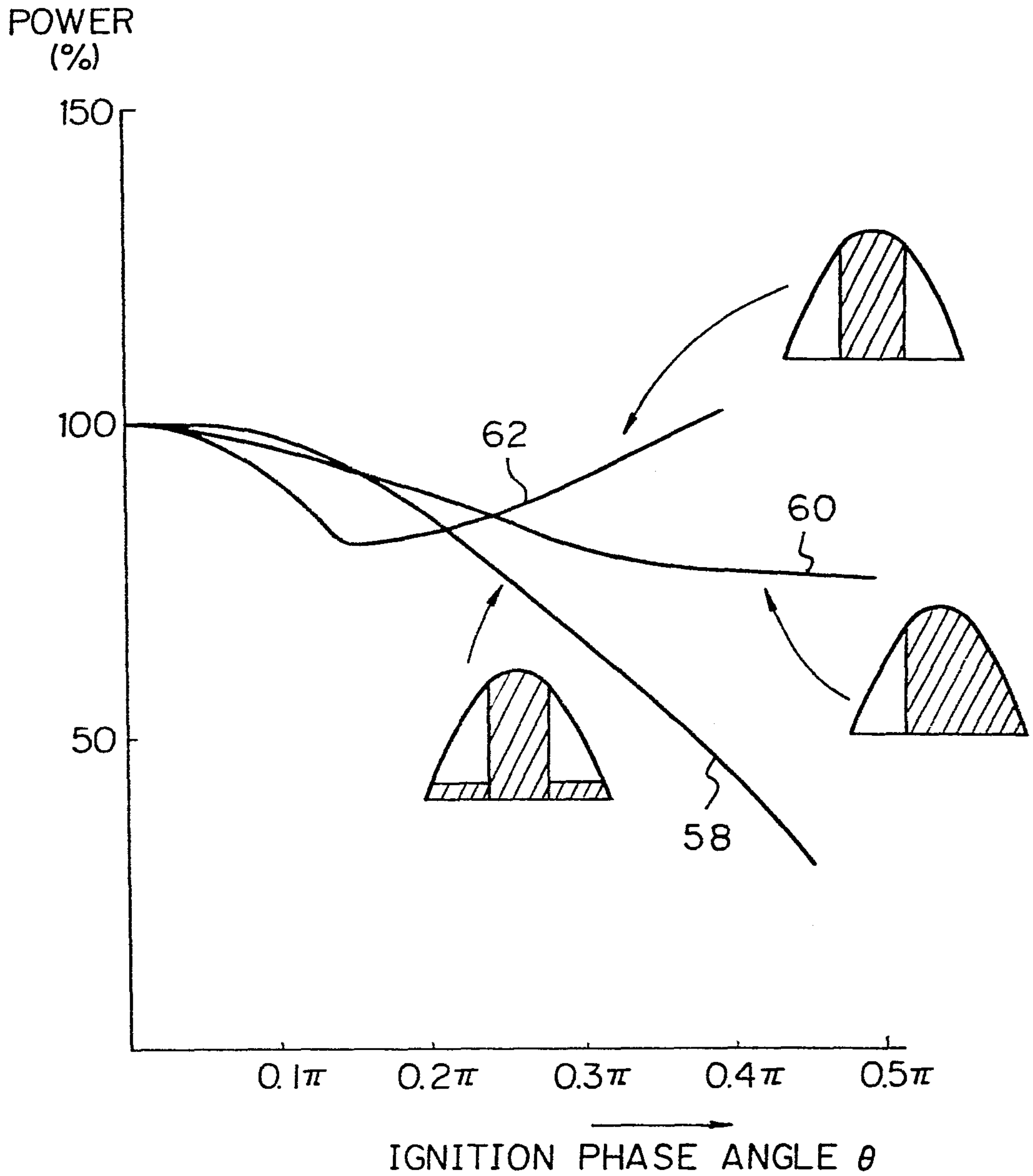


Fig. 10


POWER
(%)
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100
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62
60
58
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0.2π
0.3π
0.4π
0.5π
IGNITION PHASE ANGLE θ

European Patent Office

0143884

Application number

EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 84108745.5
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl 4)
A	GB - A - 2 062 377 (TOSHIBA) * Abstract; fig. 1 * --	1	H 05 B 41/39
A	DE - A1 - 2 831 336 (STARKSTROM-ELEKTRONIC) * Claims 12-16; fig. 1 * --	1	
A	DE - A1 - 3 002 435 (VOGT) * Totality * ----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl 4)
			H 05 B 41/00 H 05 B 39/00 H 05 B 37/00
	The present search report has been drawn up for all claims		

Place of search	Date of completion of the search	Examiner
VIENNA	04-02-1985	VAKIL

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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