

HIGH INTENSITY DISCHARGE LAMP STARTING, HOT-RESTARTING
AND OPERATING CIRCUITS

5 This invention relates to electrical circuits for starting and restarting high intensity discharge (HID) lamps under either cold or hot conditions and for operating the lamps after they are started while maintaining safe operating circumstances.

10 Those familiar with the characteristics of HID lamps are aware of the difficulty encountered when attempting to restart a lamp while it is hot after deionization due to a temporary power line dip or interruption. Without special circuit arrangements,



such lamps cannot be restarted, or are at least quite difficult to restart, until the hot, high pressure plasma gases cool down.

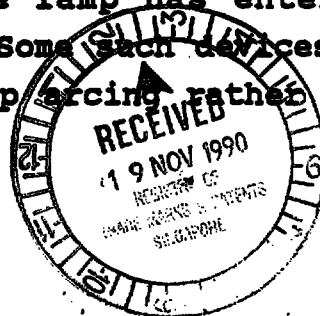
5 Then, when the lamp is cool, the fill gas is ionized by a low voltage and high current, but generates very little light output. The elements gradually heat up and re-evaporate into plasma components which then go into electrical discharge, forcing the lamp to produce the normal amount of light. While the
10 cool-down and restart sequences are occurring there is no light output produced by the lamp. The length of time can be significant: a high pressure sodium (HPS) lamp typically requires 2-3 minutes to restart in a hot fixture and 1-2 minutes more to warm up. Mercury lamps
15 typically require 4-7 minutes and metal halide 4-15 minutes.

A number of circuits have been developed for the purpose of starting such lamps while they are hot to avoid the absence of light discussed above, and other
20 circuits have been developed which simply wait a predetermined time so that restarting can be accomplished after the lamp has completely cooled. Examples of circuits which attempt to deal with the hot restart problem are found in the following U.S.
25 Patents.

3,476,977	Hallay
3,732,460	Wattenbach
3,749,968	Jones et al
3,944,876	Helmuth
30 3,991,344	Tabor
4,048,539	Walker et al
4,103,209	Elms
4,240,009	Paul
4,275,337	Knoble

4,320,325 Anderson
 4,339,692 Lasecki et al
 4,339,695 Siglock
 4,356,433 Linden
 5 4,378,514 Collins
 4,382,210 Buhrer
 4,399,392 Buhrer
 4,403,173 Mayer
 4,437,042 Morais et al
 10 4,438,369 Hicks et al
 4,455,510 Lesko
 4,461,982 Faehnrich
 4,464,607 Peil et al
 4,495,446 Brown et al
 15 4,506,195 Elms

Some circuits which have reached the market are unsuitable because they simply do not work or are not reliable, while others are unsuitable because they are unsafe. These devices apply very high voltage pulses having long base times to the wires, the sockets, the screw-shell base and the lamp structure until the hot lamp restarts, whereupon the high voltage pulses are turned off. This is a potentially dangerous situation since the presence of the high voltage is not visually apparent. Some circuits also continue to apply high voltage pulses after a lamp has failed, a condition which can result in destruction of the lamp and socket as well as presenting a danger to service personnel. Those circuits which supply pulses continuously to a lamp in an effort to hot-restart the lamp can cause the lamp to go into what is called a glow mode. Once the lamp has entered this mode it will never restart. Some such devices have been found to cause internal lamp arcing rather than the antici-



pated hot restarting, resulting in the destruction of new lamps. It is thus apparent that improvements are needed in such circuits.

5 A primary object of the present invention is to provide a circuit for reliably starting an HID lamp initially and quickly restarting the lamp when it is hot after a power interruption or the like without damage to the lamp and without shortening lamp life.

10 A further object is to provide such a circuit which does not present safety hazards.

According to the present invention we provide a starting, hot-restarting and operating circuit for a high intensity discharge lamp comprising the combination of an AC voltage source;

15 first oscillatory circuit means connected to said AC source and to said lamp for applying to said lamp a series of high voltage pulses having peak voltage magnitudes significantly greater than normal lamp operating voltage for starting or hot restarting said lamp;

20 second timing circuit means for terminating said series of pulses after a first predetermined active interval in the absence of lamp ignition, for suspending application of high voltage pulses to said lamp for a second, quiet, interval and for allowing said first
25 circuit means to again apply voltage pulses capable of causing hot restart to said lamp at the end of said quiet interval;

30 third circuit means for terminating application of said high voltage pulses to said lamp after a predetermined number of active and quiet intervals without ignition until said circuit is reset, and

ballast circuit means connected between said AC source and said lamp for controlling the AC voltage supplied to said lamp for normal AC operation of said lamp after ignition.

In order to impart full understanding of the manner in which these and other objectives are attained in accordance with the invention, particularly advantageous embodiments thereof will be described with reference to the accompanying drawings, which form a part of this specification, and wherein:

Fig. 1 is a schematic block diagram of a first embodiment of a starting and operating circuit in accordance with the invention;

Fig. 2 is a schematic circuit diagram showing the circuit of Fig. 1 in greater detail;

Fig. 3 is a schematic circuit diagram of a further embodiment of an apparatus in accordance with the invention usable with a ballast of the magnetic regulator type;

Fig. 4 is a schematic circuit diagram of a starting and operating circuit similar to that of Fig. 3 but with modified electronic circuit components;

Fig. 5 is a schematic circuit diagram of a further embodiment in accordance with the invention showing circuit components specifically intended for use with certain high pressure sodium reactor or lag ballasts.

The circuits of the present invention which will be described herein are arranged so that, when high pressure sodium lighting fixtures are specified for a particular use and are to have instant restart capabil-

ity, the circuits can be used with, or form a part of, a ballast which will instantly restart the hot sodium lamp after a momentary power outage occurs. Ideally the lamp should restart instantly when the power is restored to the ballast, regardless of the length of the power outage, if the lamp is good. As a practical matter, the longer the lamp has been out as a result of power loss, the longer it will take to return the lamp to full brightness, simply because of the cooling of internal gases which has taken place. Thus, the circuits are designed so that, when power is restored after five seconds, the light output will be at least 90% of the output prior to the outage. When power is restored after a loss of ten seconds duration, the light output will be 75%, and when power is restored after fifteen seconds, the light output should be 50%.

In addition, the instant restart circuitry should continue to function when the supply voltage is reduced as much as 10% below the designed voltage level. The added instant restart circuitry must not cause the lamp operating wattage to be reduced during normal operation more than 10% of what the normal lamp operating wattage would be on the same ballast with the instant restart components removed. The added restart components should not cause the electrical efficiency of the fixture to drop below 80% with the lamp operating within 10% of its rated wattage for lamps rated over 150 watts, or drop below 70% for 150 watt lamps and below.

As shown in Fig. 1, a basic circuit in accordance with the present invention includes a lamp 10 which can be a HPS lamp or other HID lamp, one terminal of the lamp being connected to the output of first oscillatory circuit means in the form of a pulse circuit 12.

The pulse circuit is connected to a ballast reactor 14 which is, in turn, connected to a source of AC voltage which, for purposes of the present discussion, will be assumed to be approximately 210 volts AC (RMS).

5 A voltage sensor 16 is connected in parallel with the ballast reactor and is responsive to the voltage across that reactor to produce a control output signal 17.

10 The pulse circuit is also connected to the return line of the AC supply through switches 18 and 20 which are controllable switches, switch 18 being operated by the output 17 from sensor 16. Switch 20 is controlled by an output 23 from second circuit means comprising a pulse interval timer circuit 22. Timer circuit 22 is
15 connected between the load side of the ballast and the return line and, in the embodiment of Fig. 1, is connected in series with a heating resistor 25 between the load side of the ballast reactor and the AC return line. A negative temperature coefficient (NTC)
20 resistor 26 is mounted in good heat transfer relationship with heating resistor 25, resistor 26 being connected between the input of third circuit means comprising a repeat timer circuit 28 and the AC return line. The output of timer 28 is connected to pulse
25 interval timer circuit 22.

The operation of the circuit of Fig. 1 will be described commencing with the condition in which the lamp is operating normally. Switches 18 and 20 can be viewed as normally closed switches. With load current
30 flowing through ballast reactor 14, the voltage drop across the ballast is sufficient to cause voltage sensor 16 to produce an output 17 which opens switch 18. The voltage across timer circuit 22 is insufficient to cause that circuit to operate. Thus, switch



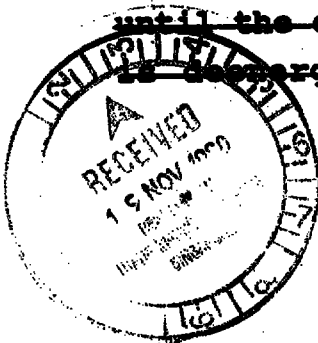
20 is closed. With switch 18 open, pulse circuit 12 is inactive and line current from the AC supply source through the reactor is delivered to the lamp which is producing light in the usual fashion.

5 When a voltage interruption occurs, lamp 10 is extinguished. When the voltage is restored, the open circuit voltage across ballast reactor 14 is very low because of the absence of current flowing through lamp 10. Thus, voltage sensor 16 produces no output
10 and both of switches 18 and 20 are closed, completing the circuit for the pulse circuit which is thus supplied with a voltage nearly equal to line voltage. Pulse circuit 12 is designed to produce a series of high voltage oscillations which are applied to lamp
15 10. Under favorable conditions, the first burst of signals from pulse circuit 12 is effective to start conduction through lamp 10, restoring the lamp to operating condition which results in voltage sensor 16 opening switch 18 and returning the circuit to the
20 operating condition described above. However, if that first burst of oscillations does not hot restart lamp 10, it is desirable to impose a "dead" or inactive interval on the system, avoiding the continued application of pulses to the lamp. Experimentation has
25 disclosed that an active interval including a sequence of fast rise-time, high voltage, limited energy oscillatory pulses and lasting for between about 0.25 seconds and about 1 second is preferably followed by an inactive interval of between about 0.5 seconds and
30 about 2.5 seconds for optimum HPS lamp hot restarting performance. The preferred values for these active and inactive intervals are 0.67 seconds and 1.5 seconds, respectively. Thus, timer circuit 22 performs the function of imposing this inactive interval on the

pulse circuit by opening switch 20 at the end of the first predetermined interval of pulse production. At the conclusion of the 0.5 to 2.5 second inactive interval, timer circuit 22 again closes switch 20 and
 5 allows the pulse circuit 12 to again supply high voltage pulses to lamp 10. If, again, ignition does not take place, this sequence of active and inactive intervals is repeated.

It is important that each active period has a
 10 length which is long enough to sufficiently ionize the lamp plasma to force its instantaneous impedance to drop down to a level at which higher magnitudes of current can be forced through the lamp by the available voltage and force it into a higher ionization level.
 15 However, the interval cannot be so long that it adds significant heating to the arc tube and deionizes gaseous components. Continuously applied high voltage energy stimulation tends to keep the arc tube and gas temperatures up, thus prolonging the time required to
 20 effect hot restarting with a practical system. The active period causes a complex sequence of ionization events to occur within the lamp. The details of this sequence are not fully understood; however, it has been clearly established that the sequence of a 0.67 second
 25 active interval followed by a 1.5 second inactive interval is optimum for a high pressure sodium lamp.

~~The circuit thus far described without resistor 26 and repeat timer 28 can be designed so that the pulse interval timer circuit does not allow a second burst of oscillations from the pulse circuit, by choosing the~~
 30 ~~time constants such that switch 20 will be latched open until the circuit is reset i.e., until the power source is reenergized and reenergized, and by selecting the~~



~~open circuit voltage of the ballast reactor higher than the lamp operating voltage.~~

~~However, a preferred form of~~ The circuit permits the repetitive sequencing of pulses from circuit 12 for a predetermined interval of time or number of cycles of active and inactive intervals after which, if ignition of lamp 10 has not yet occurred, the pulse system is deactivated until the power supply is recycled. This is accomplished by NTC resistor 26 and timer 28. As current flows through resistor 25 to pulse interval timer circuit 22, resistor 26 is heated. After a predetermined number of cycles of pulse circuit 12, the temperature of resistor 26 is elevated to a point at which its resistance is low enough to deactivate timer 28, turning off timer circuit 22 and holding the system in that state until reset when the power supply is turned off and on again.

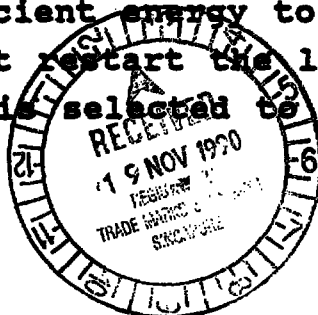
The manner in which this operation can be accomplished is illustrated in the more detailed schematic diagram of Fig. 2. As shown therein, the center contact of a socket for lamp 10 is connected to the output of a pulse transformer 30 which is preferably a toroidal transformer having a relatively small primary winding 31 and a relatively large secondary winding 32 with a turns ratio on the order of 4:200. The primary is connected to the load side of ballast 14, and voltage sensor (16) comprises a resistor 34 connected in series circuit relationship with the energizing winding 36 of a relay, the normally closed contact set or sets of which comprise switch 18. The pulse circuit further includes one or more 2-terminal semiconductor switches 38, 39, two SIDAC switches connected in series being chosen for this particular circuit application. Resistors 40 and 41 are connected in series with each

other and in parallel with the SIDAC circuit with the midpoints of the two series circuits being connected to ensure proper breakdown voltage division.

5 The resistor-SIDAC circuit is connected in parallel with the primary winding 31 of the pulse transformer and a capacitor 42, this series-parallel pulse circuit being connected in series with a second capacitor 44 and the contact sets which form switches 18 and 20.

10 During operation, capacitor 42 is charged through the circuit including winding 31, capacitor 44 and switches 18 and 20 until it reaches the breakdown voltage of SIDACS 38, 39, about 240 volts, at which time capacitor 42 is discharged through the SIDACS, causing this voltage to be applied to the primary winding. The energy stored in capacitor 42 is transferred to the toroidal core of the pulse transformer and to the effective lamp system distributed capacitance, thereby developing oscillatory high frequency pulses across the lamp having a voltage magnitude in excess of 10 KV^{peak}. It will be noted that the high voltage oscillatory energy circulates through the circuit including capacitors 42 and 44 and secondary winding 32, the tap between the windings being maintained at a relatively low voltage because the capacitors serve as a high frequency bypass for the high voltage energy. This protects the ballast and other electronic components from these high voltages.

25
30 The size of capacitor 42 is of the order of one microfarad and is selected, in conjunction with the breakdown level of the solid state switch used, to develop sufficient energy to overcome losses and to positively hot restart the lamp. The magnitude of capacitor 44 is selected to ensure placement of the



high voltage pulses on the front portion of the ballast open circuit voltage waveform as it produces a leading charging current and to develop the desired number of these high voltage pulses per half cycle. The pulses are then placed on each half cycle of the 60 Hertz open circuit voltage.

Timer circuit 22 includes the energizing winding 48 of an electromagnetic relay which controls contact set 20, the winding being connected in parallel circuit relationship with a resistor 50 and a capacitor 52. This parallel circuit is connected in series with heating resistor 25 and a semiconductor diode 54. Capacitor 52 is charged through the diode-resistance circuit until the capacitor voltage reaches the energizing voltage of winding 48 at which time the relay energizes to open switch 20, terminating the operation of pulse circuit 12. A 24 volt DC relay is suitable for this purpose, and the value of resistance 25 is chosen so that the active pulsing interval is the appropriate length.

The repeat timer circuit includes an SCR 55 which is connected through a resistor 56 to timer circuit 22. The gate electrode of the SCR is connected through a resistor 58 to the return side of the line. The gate is also connected through a breakdown device 60 in series with a resistor 61, to a series circuit including a resistor 62 and a capacitor 64. A resistor 66 is in parallel with capacitor 64 and in parallel with NTC resistor 26 to provide an upper resistance limit across capacitor 64 to establish a definite transfer point.

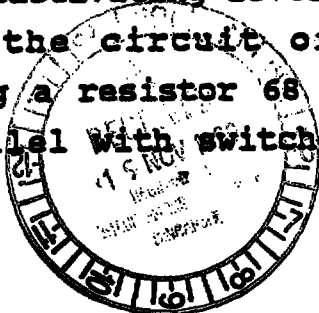
This SCR circuit forces periodic discharge of capacitor 52, thus causing the active production of pulses to occur after a predetermined inactive period.

Resistor 62, along with relatively small resistor 56, constitutes a charging circuit for capacitor 64. When the DC voltage level across capacitor 64 reaches the breakdown level of breakdown device 60, the SCR is triggered into conduction, thus discharging relatively large capacitor 52 and causing the high voltage pulsing to recommence. The SCR is commutated by the action of the collapsing field of the relay winding which forces a burst of current through resistor 50, causing a momentary voltage reversal across the SCR.

Resistor 26, which can alternatively be formed as a temperature activated normally open switch, is connected in parallel with capacitor 64. When the resistance of resistor 26 is low enough, capacitor 64 is prevented from charging to the breakdown voltage of diode 60, thereby inhibiting the action of the SCR and preventing the reestablishment of pulse energy for lamp 10. Thus, if the lamp refuses to start or hot restart after a selected interval of minutes, the high voltage pulsing circuit is turned off until the power source is turned off and back on later. The interval of minutes is selectable by choosing the characteristics of resistor 25 and the value of resistor 26 and the thermal coupling there-between. A resistor 66 is also connected in parallel with capacitor 64.

A long thermal time constant is thus accurately and reliably obtained. The time constant components do not affect normal operation because, when the lamp ignites and goes into full operation, thus limiting the open circuit voltage, the power available to heat resistor 25 is insufficient to elevate the temperature to the deactivating level of timer 28.

In the circuit of Fig. 2, a series circuit including a resistor 68 and capacitor 69 is connected in parallel with switches 18 and 20 to limit contact



arcing. The values of the components in this circuit are also chosen to cause the operating lamp voltage reignition spike to be critically damped or overdamped, preventing lamp warm-up dropout or other instabilities from occurring.

The circuit of Fig. 3 is very similar to that of Fig. 2 but is designed for use with a magnetic regulator having a primary winding 70, a secondary winding 72 which is connected to the pulsing circuit and the lamp, and a tertiary winding 73 having a capacitor 74 in parallel therewith. In this type of ballast circuit, the reactor voltage is difficult to sense. Accordingly, the voltage sensor including resistor 34 and relay winding 36 are eliminated and the energizing winding of a current sensitive relay 76 is connected in series in the lamp return line. Contact set 18 is thus operated by the current relay so that, when the lamp is operating and lamp current is flowing, relay 76 opens switch 18 to deactivate the pulse circuit. Otherwise, the operation of the embodiment of Fig. 3 is substantially the same as that of Fig. 2, the operation of the regulator itself being well understood and not being part of the present invention per se.

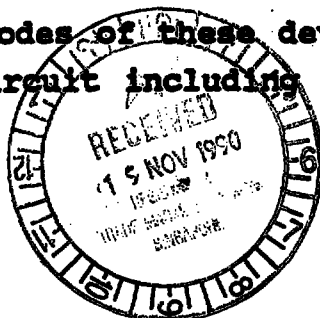
The embodiment illustrated in Fig. 4 presents modifications usable in the circuits of the previous embodiments when employing a magnetic regulator, only the secondary winding 72 of which is shown in Fig. 4. Those portions of the circuit which are similar to those shown in the previous figures will not be described again.

A capacitor 80 is connected between the positive supply line from secondary 72 and the junction between switch contacts 20 and 18. A resistor 81 is connected in parallel with capacitor 80 to provide normal

discharge when not in use. This capacitor is added to the circuit because of the open circuit voltage wave forms and the dynamic impedance characteristics of some magnetic regulators. In those regulators, there is insufficient instantaneous current available to provide "push-through" energy during hot restart. The capacitor corrects this problem, but must be eliminated from the circuit as soon as lamp operation is commenced because, if allowed to remain, it would destroy the normal lamp-ballast operational stability, performance and lamp electrode life. Opening switch 18 with the current relay 76 accomplishes this as soon as lamp operation commences.

The addition of capacitor 80, along with the magnetic regulator secondary characteristics, introduces a tendency of the entire circuit to oscillate in an undesirable fashion. Accordingly, a resistor 83 is connected in parallel circuit relationship with capacitor 44 to make the overall hot restart process more stable and positive. With the addition of this resistor, the size of capacitor 44 can be decreased since the resistor 83 carries a portion of the charging current for capacitor 42. It will be noted that resistor 83 is removed from the circuit by the opening of switch 18, except when it is needed. This prevents an increase in power loss during normal operation.

Further modifications in this circuit are the inclusion of SCR's 85 and 86 in place of the SIDAC discharge circuit used in the embodiments of Fig. 2 and 3, along with the relocation of contact set 20 and redesign of the SCR trigger circuit. SCR 86 is connected in the reverse direction from SCR 85 and the gate electrodes of these devices are interconnected by a series circuit including a resistor 87, contact set



20 and a SIDAC 88. A second SIDAC 89 is connected in parallel with contact set 20 and a resistor 78 is in parallel with SIDAC 89. A resistor 82 is in parallel with SIDAC 88. Trigger diodes 91 and 93 are connected between the gate and anode electrodes of SCR's 85 and 86, respectively. A series resistor 79 and capacitor 84 are connected across the SCR's. The relocation of contacts 20 from the main capacitive current loop into the SCR trigger circuit greatly increases relay contact life and reliability without changing the basic function. When relay winding 48 is energized, contact set 20 is opened, preventing the SCR's from firing under normal operating conditions, turning off the high voltage pulse generation. However, those contacts need only carry gate current.

SIDAC 89 is included to make the SCR's self-protecting. In the event that a higher than normal voltage appears across the SCR's when contact set 20 is open, the forward biased SCR is turned on by SIDAC 89 breakdown, thereby protecting the network. Resistors 82 and 78 force proper voltage division between SIDAC's 88 and 89. Normal operating voltage levels will not break down the two series-connected SIDAC's but a high, destructive transient or surge will. When contact set 20 is closed, SIDAC 89 is shunted and SIDAC 88 breaks down normally. The network including resistor 79 and capacitor 84 is included to dissipate very high frequency spurious oscillations which tend to degrade SCR reliability. The circuit, as shown, behaves very much like the SIDAC circuit of Fig. 3 but is capable of handling much more switching energy.

The reason for this modification involves differences in the characteristics of the magnetic regulator ballast, the peak and RMS voltages of which are lower

than the reactor open circuit voltage values. Because the regulator ballast delivers less total energy, it was necessary to increase the amount of energy delivered in the high voltages pulses from pulse transformer 30 and capacitor 80.

The charging circuit for capacitor 52 and for the SCR 55 is different in that the charging circuit includes series resistors 90 and 92. Because the voltage waveform from secondary 72 is lower in magnitude, a longer time-constant circuit requires increased charging rate driving voltage and linearity to effectively and repeatedly trigger the SCR. The gate circuit is therefore modified to include an SBS breakdown device 94 connected in parallel circuit relationship with a capacitor 95 and to a series resistor 96 the other end of which is connected between resistors 90 and 92. Capacitor 95 insures positive voltage breakdown of SBS 94. The operation of this circuit is essentially the same as previously described.

Fig. 5 illustrates the circuit for an embodiment which is quite similar to that of Fig. 4 but is designed for use with a reactor ballast 98. The major differences from Fig. 4 are in circuit values and in the incorporation of an SUS breakdown device 102 in the gate circuit for SCR 55. The circuit shown in Fig. 5 is particularly useful in connection with a 250 watt, 100 volt HPS lamp.

The following tables give the values for the circuits described.



TABLE 1: COMPONENT VALUES, FIG. 2

Transformer 30 turns ratio, 4:200

5	Capacitor	42	1.5	mfd
	"	44	4	"
	"	52	1000	"
	"	64	100	"
	"	69	0.22	"
10	Resistor	25	5K	Ohms
	"	26	90K Ohms at cutoff	
	"	40	100K	Ohms
	"	41	100K	"
	"	43	100K	"
15	"	50	270	"
	"	56	100	"
	"	58	1K	"
	"	61	470	"
	"	62	150K	"
	"	66	470K	"
20	"	68	470	"

TABLE 2: COMPONENT VALUES, FIG. 3

25	Capacitor	42	1.5	mfd
	"	44	5	"
	"	52	1200	"
	"	64	100	"
	"	69	0.22	"
	Resistor	25	5K	Ohms
	"	40	100K	"
	"	41	100K	"
	"	43	100K	"

5	"	50	270	"
	"	56	100	"
	"	58	1K	"
	"	61	470	"
	"	66	470K	"
	"	68	470	"

TABLE 3: COMPONENT VALUES, FIG. 4

10	Capacitor	42	2.7	mfd
	"	44	4.0	"
	"	52	560	"
	"	64	50	"
	"	69	0.22	"
	"	80	3.9	"
	"	95	100	mmfd
15	Resistor	56	27	Ohms
	"	65	100	"
	"	66	470K	"
	"	68	470	"
	"	78	470K	"
	"	81	470K	"
	"	82	470K	"
	"	83	300	"
	"	87	470	"
20	"	90	2.5K	"
	"	92	2.5K	"
	"	96	330K	"
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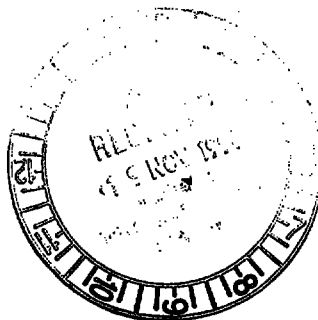


TABLE 4: COMPONENT VALUES, FIG. 5

Transformer 30 turns ratio 7:200

5	Capacitor	42	1.5	mfd
	"	44	8	"
	"	52	560	"
	"	64	50	"
	"	69	0.22	"
	"	80	2	"
10	"	95	100	pf
	Resistor	56	27	Ohms
	"	65	100	"
	"	66	470K	"
	"	78	470K	"
	"	68	470	"
15	"	81	470K	"
	"	82	470K	"
	"	83	300	"
	"	87	470	"
	"	90	2.5K	"
	"	92	2.5K	"
20	"	96	330K	"

~~TABLE 5: COMPONENT VALUES, FIG. 6~~~~Transformer 30 turns ratio 4:200~~

25	~~Capacitor~~	~~111~~	~~2.7~~	~~mfd~~
	~~"~~	~~113~~	~~6~~	~~"~~
	~~"~~	~~127~~	~~1200~~	~~"~~

CLAIMS

1. A starting, hot-restarting and operating circuit for a high intensity discharge lamp comprising the combination of

an AC voltage source;

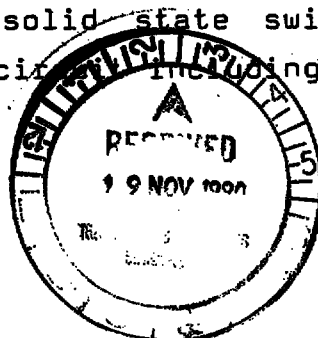
5 first oscillatory circuit means connected to said AC source and to said lamp for applying to said lamp a series of high voltage pulses having peak voltage magnitudes significantly greater than normal lamp operating voltage for starting or hot restarting said lamp;

10 second timing circuit means for terminating said series of pulses after a first predetermined active interval in the absence of lamp ignition, for suspending application of high voltage pulses to said lamp for a second, quiet, interval and for allowing said first circuit means to again apply voltage pulses capable of causing hot restart to said lamp at the end
15 of said quiet interval;

third circuit means for terminating application of said high voltage pulses to said lamp after a predetermined number of active and quiet intervals without ignition until said circuit is reset, and

20 ballast circuit means connected between said AC source and said lamp for controlling the AC voltage supplied to said lamp for normal AC operation of said lamp after ignition.

2. A circuit according to Claim 1, wherein said first circuit means includes a pulse transformer having a toroidal core, a secondary winding connected to said lamp, a primary winding, a capacitor connected in series with said primary winding and a solid state switch connected in parallel with the series circuit including said capacitor and primary winding.



3. A circuit according to claim 1 or 2 wherein said second circuit means includes a normally conductive controllable switch means in series with said first circuit means so that opening said switch means deactivates said first circuit means, and

timing means connected to said AC source for opening said switch means after said first predetermined active interval to suspend application of said pulses.

4. A circuit according to claim 3 wherein said timing means includes a resistor, a diode and a capacitor connected in series across said AC source.

5. A circuit according to claim 4 wherein said controllable switch means includes a relay having a normally closed contact set and an energizing winding connected to said resistor-diode-capacitor circuit.

6. A circuit according to claim 3, 4 or 5 wherein said second circuit means further includes means for rapidly discharging said capacitor at the end of said quiet interval to reclose said switch means.

7. A circuit according to claim 6 wherein said means for discharging includes a triggerable semiconductor switch connected in parallel with said capacitor and a gating circuit having a time constant for establishing the duration of said quiet interval.

8. A circuit according to claim 7 wherein said third circuit means includes a heating resistor connected across said AC source and a negative temperature coefficient resistor thermally coupled to said heating



resistor and connected to said gating circuit, the resistance of said NTC resistor being reduced after an interval of heating to a value at which said gating circuit becomes inoperative.

5 9. A circuit according to any of Claims 3 to 7 wherein said third circuit means includes a heating element and means thermally responsive thereto for keeping said switch means open.

10 10. A starting, hot-restarting and operating circuit for a high intensity discharge lamp, substantially as hereinbefore described with reference to Figs. 1 and 2, Fig. 3, Fig. 4 or Fig. 5 of the accompanying drawings.

