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(54) Electronic starter circuit for discharge lamps.

(57) Starter circuits are disclosed for a fluorescent discharge tube (10) of the type having a pair of heater cathodes between which the discharge is struck and which are connectable to the mains supply (V_s) through a ballast inductor (L). The starter circuit (20) includes a thyristor (SCR) that conducts current through the ballast inductor and heaters on half-cycles on one polarity. A gate control circuit (30) includes a capacitor (C_1) that receives a controlled (by C_2, Z_1) bias voltage increment in each such half-cycle to eventually terminate triggering of the thyristor (SCR). Preferably an automatic switching arrangement (C_3, Z_2) changes the value of capacitance to give a lesser rate of increment upon a certain bias level being reached to provide a two phase start operation that eventually times out. Alternatively, the maximum bias may be clamped and a positive temperature coefficient resistor (PTC) carrying the heater current terminates the second phase upon heating to a predetermined resistance. The starter circuit (20) also includes a non-linear dielectric element (NLDE) that cooperates with the inductor to generate striking voltage for the tube and that is connected in an ignition circuit including a capacitor (C_6) connected to the thyristor (SCR) to charge and maintain the NLDE quiescent during normal operation but to be discharged by the thyristor (SCR) during starting to allow the NLDE to achieve saturation and coact with the ballast inductor (L).

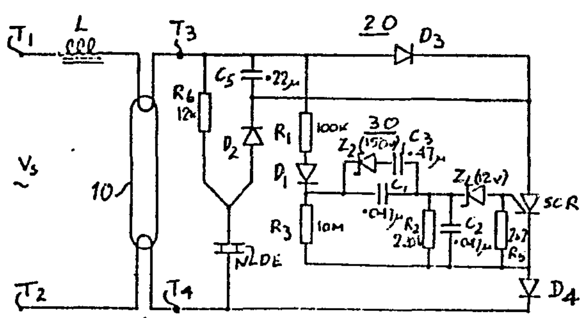

FIG. 6

EP 0 170 528 A2

Croydon Printing Company Ltd.

Title: Electronic Starter Circuit for Discharge Lamps

This invention relates to electronic starter circuits for discharge lamps having pre-heated cathodes and particularly for fluorescent discharge lamps.

Recent years have seen developments in electronic starter circuits for the conventional fluorescent discharge tube having a respective heater cathode at each end. The tube is connected to the a.c. mains supply such that on starting current is drawn through a series circuit comprising a ballast inductor, the two cathode heaters and an electronic starter circuit that is connected between the two cathode heaters. It is generally desirable to provide a fast heating of the cathodes. The starter circuit is arranged also to provide in conjunction with the ballast inductor, trigger voltages across the cathodes to cause the discharge tube to strike. Thereafter, the starter circuit should become effectively inoperative.

A relatively simple circuit for this purpose is described in patent specification G.B. 1223733 in which the electronic starter circuit utilises an SCR as the controlled element to control the initial heater current, the thyristor being rendered conductive in half-cycles of one polarity. When the tube strikes, it shunts the thyristor circuit and renders it inoperative. Another such circuit is disclosed in patent specification 1264397 which provides the additional facility of cutting-off the thyristor operation after an interval if the tube has not struck. This is done by incrementally charging a capacitor biasing the thyristor gate in each mains cycle so that the trigger point in successive cycles is advanced until the thyristor no longer triggers.

A further discussion of both these circuits may be found in patent specification GB 1602456 which goes on to disclose further thyristor control circuits in which a capacitor is incrementally charged over successive cycles to effectively bias the gate beyond the point of triggering if the tube does not strike. Specification GB 1602456 discloses a bias that advances at an essentially fixed rate with time, that is with respect to the number of mains cycles since the circuit was switched on.

In these various circuits, the voltage required to strike the tube is generated with the aid of the inductor, and possibly an auxiliary capacitor, at a time when the thyristor current drops to zero and the thyristor turns off.

Another development in fluorescent tube starter circuits has been the adoption of non-linear dielectric elements (NLDEs) based on piezo-electric materials. Such an element, also known as a voltage dependent capacitor, has the property of charging like a capacitor up to a certain voltage at which it saturates and charges no further. If such an element is used in conjunction with an inductor, the interruption upon reaching saturation of charging current supplied to the element through the inductor produces a voltage spike across the inductor which can be used to strike the tube. Various circuits employing NLDEs are described in patent specifications EP 0048137B and EP 0102183.

One aspect of the present invention is concerned with starter circuits in which an incrementing bias is applied to eventually terminate triggering of the starter if the lamp has not struck. A particular aspect is the provision of means to provide a time delay in the operation of the circuit on a fresh mains cycle.

If such a starter circuit is to be able to provide an adequate interval to allow starting under adverse conditions, the rate at which the bias increments may actually prevent full starting as early as could be done under normal conditions. Another aspect of the invention is to provide a circuit in which the available starting period is divided into two intervals having different operational characteristics. This is described hereinafter in terms of what are called dual rate or dual slope circuits. The dual rate or slope may arise from different rates of incrementing the bias, or from a phase with an incrementing bias followed by a phase with essentially a fixed bias that is timed out by some other means, such as the use of a positive temperature coefficient resistor heated by the starter current.

Another aspect of the invention is concerned with the use of NLDEs and in particular a circuit arrangement to use the device in generating high striking voltages during the starting of the lamp but to maintain the NLDE quiescent during normal running.

Various aspects and features of the invention are set out in the appended claims.

The invention and its practice will be described with reference to the accompanying drawings in which:

Fig. 1 shows a fluorescent tube circuit including a starter circuit in accord with the invention;

Fig. 2 shows another fluorescent tube circuit whose starter circuit includes a gate control circuit having a dual-rate characteristic;

Figs. 3 and 4 are graphs pertaining to the operation of the circuit of Fig. 2, and show trigger voltage and heater current respectively as a function of time;

Fig. 5 shows a modification of the gate control circuit shown in Fig. 2;

Fig. 6 shows another fluorescent tube circuit including an NLDE for the generation of the striking voltage for the tube;

Figs. 7A and 7B are graphical representations relating to the operation of the circuit of Fig. 6, and Fig. 7C shows typical waveforms for one cycle of operation;

Fig. 8 is a graphical illustration contrasting the single rate operation of the circuit of Fig. 1 with the dual rate operation of the circuits of Figs. 2 and 6;

Fig. 9 shows a modification of the circuit of Fig. 2 to include the use of a PTC resistor both for protection and to control one phase of the dual-rate triggering operation; and

Figs. 10 and 11 are graphs corresponding to Figs. 3 and 4 but illustrating the operation of the circuit of Fig. 9.

In the figures like reference designations indicate like parts.

Referring to Fig. 1, a discharge lamp 10 is shown as being of the conventional fluorescent lamp type having a heater cathode at each end. The lamp is connected to the mains supply V_s applied between terminals T_1, T_2 through a ballast inductor L. A starter circuit 20 is connected in series with the inductor and the two heater cathodes between supply terminals T_1, T_2.

The starter circuit includes a controlled switching element such as a thyristor shown in this example as an SCR providing a half-wave control the current through the heater circuit. The gate control circuit of the SCR is denoted 30 and is responsive to the supply voltage as it appears across the tube to control the triggering of the SCR gate. The gate circuit comprises a resistor R1 which supplies current via diode D_1 on positive half-cycles to a timing capacitor C_1 in series with the SCR gate. The charging current also flows to a second capacitor C_2 in parallel with the gate-cathode circuit of the SCR. Resistors R_2 and R_3 provide discharge paths for C_2 and C_1. The voltage developed across C_2 is applied to the SCR gate through a zener diode Z_1 and resistor R_5 which defines a set threshold voltage that must be reached for the SCR to be triggered.

In addition to the gate control circuit 30, the starter circuit includes a series capacitor-resistor combination C_4, R_4 connected in parallel with the lamp 10 and co-operable with the inductor L to provide a striking voltage pulse across the lamp 10 as will be described below.

In operation of the starting circuit of Fig. 1, the charging of the timing capacitor C_1 is controlled by a second capacitor C_2. For the thyristor to trigger the voltage on C_2 must be approximately equal to the voltage of zener diode Z_1. As the current charging C_2 must flow in C_1, the voltage increment on C_1 for each cycle is defined ($\delta V_{C_1} \doteq V_{Z_1} . C_2/C_1$). R_2 is of a value low enough to discharge C_2 whilst the thyristor is conducting so that C_2 is discharged ready for the next charging cycle. R_3 is a high value resistor which has little effect during the starting sequence but which discharges C_1 when the starter becomes inactive on striking of the lamp, ready for the next start operation. The circuit of Fig. 2 provides a well-defined trigger threshold and a well-defined incrementing of the bias voltage on capacitor C_1 which has to be overcome by the voltage applied to the starter circuit. Thus the trigger point for the SCR advances further in successive positive half-cycles. To obtain tube ignition, a high voltage pulse must also be applied following the pulse of heater current in each cycle. For tubes with an

Argon gas fill, a sufficiently high negative peak of voltage can be obtained by means of C_4 placed across the tube cathodes. When the thyristor SCR stops conducting, C_4 forms a resonant circuit with the ballast inductor to give a voltage overswing having a peak value of approximately 600v. (R_4 is placed in series with C_4 to limit the discharge current when the thyristor switches on again.) The circuit of Fig. 1 is suitable, as shown, for starting Argon tubes up to 65w.

The resistor R_1 is chosen not to significantly impede the desired charging of C_1 and C_2 but to provide with C_1/C_2 a time delay of say 2mS to give time for the lamp to ionize and conduct before the thyristor again triggers. It will be appreciated that although the SCR is triggered in the positive half-cycle, the build-up of current is determined by the ballast inductor, reaching a peak at about the time of the next zero crossing and decaying during the following negative half-cycle, the SCR remaining conductive essentially until the current falls to zero. At this time the negative voltage acts on the resonant circuit provided by L, C_4 to provide the striking voltage across the lamp.

The rate of increase of trigger voltage in the circuit of Fig. 1 is substantially constant, and will determine the maximum time for which the starter circuit can remain active before the bias voltage reaches a level (the peak voltage of the supply) at which the SCR is no longer rendered conductive. It will also determine the minimum time taken for the tube conduction to become fully established. This is because at first the voltage level on which the SCR is triggered is lower than the re-ignition voltage required to produce positive conduction in the tube immediately following a negative conduction period, that is conduction in a positive half-cycle following a negative half-cycle in which the tube is struck. Thus, even though the cathodes may be sufficiently heated and the high negative voltage is causing negative tube conduction on successive half cycles, the positive conduction and therefore full running of the tube which could take place is actually inhibited by the starter re-triggering the SCR until the required applied voltage at which triggering takes place rises, i.e. increments in the way described, to a value equal to the positive re-ignition voltage, typically 250V for a 58 watt tube. For the fastest possible start then, the rate of increase according to this consideration needs to be high enough to provide just enough cathode heating by the time the trigger voltage level reaches 250V in the example cited. However, the rate cannot be chosen using this criterion applied to normal conditions but only to worst case conditions. If the rate is too high, then under conditions of low mains voltage, low temperature, end of life tube etc. the trigger voltage would have risen to the peak supply voltage and the starter therefore rendered inactive before the cathodes are sufficiently heated to provide tube conduction. The rate must therefore be selected to be sufficiently low to cater for adverse conditions, thus compromising the preferred higher rate which would give the faster start under normal conditions. It will be understood that in accord with what has just been said the trigger voltage referred to herein is that value of the applied voltage at which the SCR is caused to trigger into conduction.

The circuit of Fig. 2 is intended to provide a balance between these requirements by providing a dual rate of control of the triggering of the SCR. The circuit is the same as that of Fig. 1 except that a series combination of a further capacitor C_3 and a zener diode Z_2 is placed in parallel with timing capacitor C_1. Z_2 acts as an automatic switch to place C_3 in parallel with C_1, and thereby increase, the timing capacitance, upon the voltage across C_1 reaching the zener voltage of Z_2. Operation is similar to the circuit of Fig. 1 except that the finite charge per cycle as governed by C_2 now charges C_1 until the voltage across C_1 reaches the breakdown voltage of zener diode Z_2. The charge then has to flow in C_1 and C_3 in parallel thus reducing the voltage bias increment occurring in each cycle in the ratio $\frac{C_1}{C_1 + C_3}$. The trigger voltage v. time characteristic therefore becomes as shown in Fig. 3 with the heater current characteristic as in Fig. 4. The trigger voltage at which the rate changes (V_{BK} in Fig. 3) is chosen to be a value at which positive conduction in the tube can initiate.

The trigger voltage is the voltage at terminals T_3, T_4 at which the SCR is rendered conductive. The voltage rises eventually to $\hat{V}_s$, the maximum of the supply voltage, i.e. the peak of a positive half-cycle, at which time the SCR can no longer be triggered. The heater current shown in Fig. 4 starts at a high level reducing relatively rapidly until the trigger voltage V_{BK} is reached, whereupon with the reduced rate of trigger voltage increase, the heater current falls more slowly, thereby giving time for sufficient heating of the cathodes under adverse conditions before the starter is finally rendered inactive.

Fig. 5 shows a variation of the gate control circuit (the remaining circuitry is not repeated) for switching the extra capacitor C_3 by means of Z_2. In Fig. 5, C_3 and C_1 are in series at the outset, Z_2 providing an open circuit switch. When the voltage on C_3 reaches the breakdown voltage of Z_2, it is clamped at the voltage of Z_2 which becomes a closed switch for charging C_1 so that the effective capacitance increases to that of C_1.

The embodiments thus far described show the provision of a capacitor C_4 to resonate with the ballast inductor L to generate the striking voltage across the tube. Thus voltage may be up to twice the supply peak voltage. For Krypton filled tubes however, a pulse of at least 1000v is normally required. This can be generated using a non-linear dielectric element (NLDE), also known as a voltage dependent capacitor. The characteristics of such devices are described in the aforementioned Specification EP 0102183. NLDEs are available from the TDK Electronics Corporation of Japan. As shown in the just-mentioned specification the NLDE has a saturating charge/voltage characteristic that shows hysteresis and for a time-varying voltage provides a current peak as the device charges to saturation positively or negatively. When the voltage applied to an NLDE reaches a certain threshold it takes current until a finite charge is stored at which point it becomes saturated and cannot sustain further current. Placed in series with a fluorescent lamp ballast choke, current flows in the choke until the NLDE is saturated. When the NLDE becomes saturated and cannot sustain the current now flowing in the choke, a large induced EMF is generated by the choke.

The use of an NLDE will be described with reference to the circuit shown in Fig. 6 which shows a starter circuit which includes a gate control circuit for the SCR similar to that of Fig. 2 but in which the resonating capacitor C_4 is replaced by an NLDE in a circuit that is considered novel and inventive in its own right.

If the NLDE were placed directly across the ends of lamp 10 it would then cause high voltage generation both in the positive and negative half-cycles (thus interfering with the thyristor triggering arrangements) and also, when the tube is running, it would continue to generate high voltage pulses. The circuit of Fig. 6 avoids these disadvantages. The NLDE is connected across the tube via a resistor R_6 for charging in one direction (positive polarity) and via a series capacitor and diode combination (C_5,D_2) in parallel with R_6 for charging on the opposite polarity half-cycles. The junction of C_5, D_2 is connected to the SCR anode and an isolation diode D_3 is inserted in the anode line. The resistor R_6 ensures that the NLDE is set in the positive direction but that the current is not high enough to give a significant induced EMF. The negative feed to the NLDE is via the capacitor C_5 which charges on the negative half-cycles. In the triggering (start) mode, the capacitor C_5 does not greatly affect the negative current to the NLDE because each time the thyristor triggers it discharges C_5 before taking current from the ballast via diode D_3. Once the thyristor stops triggering however, charge builds up on C_5 rendering the NLDE quiescent.

Fig. 6 therefore shows a complete dual-rate starter in which positive conduction is accompanied by high voltage generation in the negative half-cycle.

The heater current and high voltage pulse change with time as shown in Figs. 7A and 7B respectively. (The onset of high voltage pulses is delayed at first because the initial low trigger voltage is not sufficient to set the NLDE in the positive polarity therefore no negative transition occurs.) A diode D_4 in Fig. 6 isolates the high negative pulse generated by the NLDE from the rest of the circuit.

The repetition waveforms occurring as the trigger point reaches V_{BK} are as shown in Fig. 7C. The dash, full and dotted lines show the mains supply voltage, voltage across the lamp or tube, and the cathode heater current respectively. With appropriate choice of components this can be arranged to be appropriate for starting a tube completely, provided the cathodes are sufficiently heated. A typical time of 0.3 seconds (t_1) to reach V_{BK} is normally sufficient for this to happen. Should the heating not be sufficient because of adverse conditions, then the starter continues to be active giving the additional heating required.

The firing angle now changes only slowly to give effective longer heating, but eventually times out completely if the tube fails to strike. This latter feature is necessary in order to prevent ballast overheating and annoying flashing, both of which can occur if a tube is faulty.

Fig. 8 illustrates the comparison between the locus of trigger voltage levels for the dual slope system described compared with a single slope system. Times are typical for a 58 watt tube. The component values corresponding to the times and levels of Fig. 8 are shown in Fig. 6. To illustrate the earlier discussion of the problem with single rate starter circuits it will be noted that if the trigger voltage V_{trig} of the single rate starter lies below V_{BK} then even if the tube is capable of starting at a time less than t_4 ($V_{trig} = V_{BK}$), then the tube will not fully ignite due to continual retriggering in the starter circuit. A typical value for t_4 is 1.2 seconds, after which the tube ignites normally. The dual rate has the tube lit in under 0.3 seconds in normal operation. If starting fails the starter times out at t_5 as compared with the shorter t_6 in the single rate case.

It may prove desirable to provide some form of independent current sensing to cause cut-out under starter fault conditions. Such provision may use a positive temperature coefficient resistor (PTC).

A PTC can be added to the circuits of Figs. 1, 2 and 6, for example, by breaking the circuit at terminal T_3 and inserting the PTC at that point. However, advantage can be taken of the inclusion of the PTC to replace the function of the second time constant in the dual rate circuits of Figs. 2 and 6. Fig. 9 shows a modified version of Fig. 2 in which the zener diode Z_2 and capacitor C_3 are omitted but further voltage clamping zener diode Z_4 is provided as shown to define a limit V_{BK} to the bias voltage developed across C_1. In this case the voltage is not allowed to rise to $\hat{V}_s$ (see Fig. 3) so that the circuit continues to trigger to provide reduced heater current in the second phase of operation until the PTC heats to a resistance value that cuts out starter operation entirely, there being insufficient voltage available to the starter circuit to produce triggering. This is shown in Figs. 10 and 11 where (compare Figs. 3 and 4 respectively) after the initial fast ramp-up of trigger voltage to V_{BK} at t_1, the triggering remains constant until the cut-out phase at t_2. As the PTC cools, the voltage fed to the starter circuit itself slowly increases. However, the rate of increase is very slow so that each successive cycle of applied mains results in only a very small charging current in C_1 to the extent that the voltage thereby caused at C_2 is less than the voltage of Z_1, so the thyristor is not triggered. The PTC therefore cools completely (re-sets) without the starter triggering and it is not until the power is removed (either by switching off or removing the tube) that C_1 can discharge and allow the starter to operate next time power is applied. The PTC causes the circuit to remain inoperative for a period until at t_3 the PTC has cooled sufficiently to allow a fresh start operation to commence.

The circuit of Fig. 6 using the NLDE can be modified in the same manner as indicated in Fig. 9.

In Fig. 8, the value of V_{BK} is assumed to be equal to the positive tube conduction voltage threshold so that a circuit having a given V_{BK} will work with tubes of any lesser threshold characteristic.

Claims

1. A starter circuit for a discharge lamp of the kind having cathode heaters energizable from an a.c. supply comprising:

conductors connectable to the respective cathode heaters,

a thyristor connected between the conductors to provide a controllable path for heater current,

a gate circuit for triggering said thyristor connected to receive the supply voltage applied across the cathodes,

said gate circuit including first and second capacitors interconnected for charging by the applied supply voltage, said first capacitor being connected in series with the thyristor gate to acquire an increment of bias voltage each time the thyristor is triggered so as to cause triggering to be increasingly delayed in successive supply cycles in response to the increasing bias voltage established across the first capacitor,

said second capacitor being connected with means ensuring that the second capacitor receives a substantially fixed increment of charge in each supply cycle, and

the interconnection of the capacitors providing that the sharing of charge therebetween is such that the first capacitor acquires a fixed increment of bias voltage in each supply cycle.

2. A circuit as claimed in Claim 1 in which said means connected with the second capacitor defines a predetermined voltage developed thereon in each supply cycle.

3. A starter circuit as claimed in Claim 2 in which said voltage defining means comprises a Zener diode.

4. A starter circuit as claimed in Claim 3 in which the second capacitor is connected across the gate and cathode of the thyristor and is connected to the gate through the Zener diode.

5. A starter circuit as claimed in any one of Claims 1 to 4, in which one of said first and second capacitors comprises two capacitor elements and voltage dependent means for switching one of the two elements upon the first capacitor achieving a predetermined bias voltage thereacross such that thereafter a lesser voltage bias increment is acquired by the first capacitor in each supply cycle.

6. A starter circuit as claimed in Claim 5 in which said first capacitor comprises the two capacitor elements.

7. A starter circuit as claimed in Claim 6 in which said switching means comprises a Zener diode and is connected in a series combination with one capacitor element of the first capacitor, the other capacitor element being connected in parallel with said series combination.

8. A starter circuit as claimed in Claim 6 in which said switching means comprises a Zener diode and is connected in a parallel combination with one capacitor element of the first capacitor, the other capacitor element being connected in series with said parallel combination.

9. A starter circuit as claimed in any preceding claim for use with a discharge lamp of the kind stated operable with a ballast choke connected in series between the lamp heaters and the a.c. supply, the starter circuit further comprising means connected between said conductors and cooperable with the ballast choke, when in circuit with the lamp, to generate a voltage spike across the conductors to initiate discharge in the lamp in response to the turning-off of the thyristor.

10. A starter circuit as claimed in Claim 9 in which the voltage spike generating means comprises a non-linear dielectric element chargeable to saturation by current maintained through the ballast choke upon said thyristor turning-off.

11. A starter circuit as claimed in Claim 10 in which said thyristor is operable to be triggered only on supply half-cycles of a given polarity, and said non-linear dielectric device is connected in a first circuit path between said conductors that enables the device to be charged to saturation as aforesaid following triggering of said thyristor in half cycle of said given polarity, and in a second circuit path that enables the device

to be discharged from the saturated condition in the next following half-cycle.

12. A starter circuit as claimed in Claim 11 in which the second circuit path includes a capacitor, this capacitor being connected to said thyristor for discharge when the thyristor turns on, and being dimensioned to prevent the generation of voltage spikes during normal lamp discharge when the thyristor remains off.

13. A starter circuit as claimed in any one of Claims 9 to 12 comprising a resistor in series in the charging path of the first and second capacitors to provide a time delay therewith to allow initiation of discharge by a voltage spike prior to a further triggering of said thyristor.

14. A starter circuit as claimed in any preceding claim further including a positive temperature coefficient resistor connected in series with said thyristor.

15. A starter circuit for a discharge lamp connectable to an energising a.c. supply and having heater cathodes between which the discharge is struck, and comprising a thyristor connectable in series with the heater cathodes to control the supply of heater current therethrough and a control circuit for the thyristor arranged to terminate operation of the starting circuit after an interval if the lamp fails to strike,

characterised by the control circuit operating in two phases and including first means for incrementing the voltage at which the thyristor is rendered conductive in successive half-cycles of the supply in a first phase, and second means for maintaining said voltage achieved at the end of the first phase, or for incrementing said voltage at a lesser rate, for a further period constituting said second phase.

16. A starter circuit as claimed in Claim 15 in which said first means comprises capacitance on which a bias voltage is developed and incremented in successive half-cycles of said first phase, and said second means responsive to the bias voltage reaching a predetermined value to change the value of said capacitance such that the bias value increments at a lesser rate in the second phase.

17. A starter circuit as claimed in Claim 16 in which triggering of the thyristor ceases when the bias voltage reaches a predetermined value at which time the second phase terminates.

18. A starter circuit as claimed in Claim 15 in which said first means comprises capacitance on which a bias voltage is developed and incremented in successive half-cycles of said first phase, and said second means comprises means for limiting the maximum value of said bias voltage to a value at which the thyristor continues

to be rendered conductive in successive half-cycles and a positive temperature coefficient resistor connected to carry the cathode heater current and to terminate said second phase upon the resistor reaching a predetermined temperature.

19. A starter circuit as claimed in Claim 18 in which said capacitance is so arranged that it is discharged at the end of said second phase and the thyristor is not triggered into conduction again until said resistor has substantially cooled.

20. A starter circuit as claimed in any one of Claims 15 to 19 for a discharge lamp having an inductor in series with its heater cathodes in the energising circuit, the starter circuit further comprising an NLDE in an ignition circuit connectable across the heater cathodes in parallel with the lamp, the ignition circuit comprising two parallel paths connected to the NLDE, one path including a circuit element providing current flow to the NLDE in half-cycles of one polarity, the other path comprising a series capacitor and means providing current flow from the NLDE into the capacitor in half-cycles of the opposite polarity whereby during the normal operation of the lamp the capacitor achieves a bias voltage that maintains the NLDE in a substantially quiescent state, and the capacitor in said other path being connected to the thyristor for discharge when the thyristor is rendered

conductive whereby during said first and second phases the NLDE is coactable with such a series inductor to generate voltage spikes to strike the lamp.

21. A starter circuit as claimed in Claim 20 in which said one path comprises resistance and said means in the other path comprises a unidirectionally conductive device.

22. A starter circuit for a discharge lamp having heater cathodes between which the discharge is struck and which are connectable in a series circuit with an inductor, the starter circuit including a thyristor connectable in said series circuit to control the heater current, and an ignition circuit connectable between said cathodes in parallel with the lamp and including an NLDE to cooperate with the inductor to generate high voltage to strike the lamp, the ignition circuit comprising two parallel paths connected to the NLDE, one path including a circuit element providing current flow to the NLDE in half-cycles of one polarity, the other path comprising a series capacitor and means providing current flow from the NLDE into the capacitor in half-cycles of the opposite polarity whereby during the normal operation of the lamp the capacitor achieves a bias voltage that maintains the NLDE in a substantially quiescent state, and the capacitor in said other path being connected to the thyristor for discharge when the

thyristor is rendered conductive whereby during active operation of the starter circuit, the NLDE is coactable with such a series inductor to generate voltage spikes to strike the lamp.

23. A starter circuit as claimed in Claim 22 in which said one path comprises resistance and said means in the other path comprises a unidirectionally conductive device.

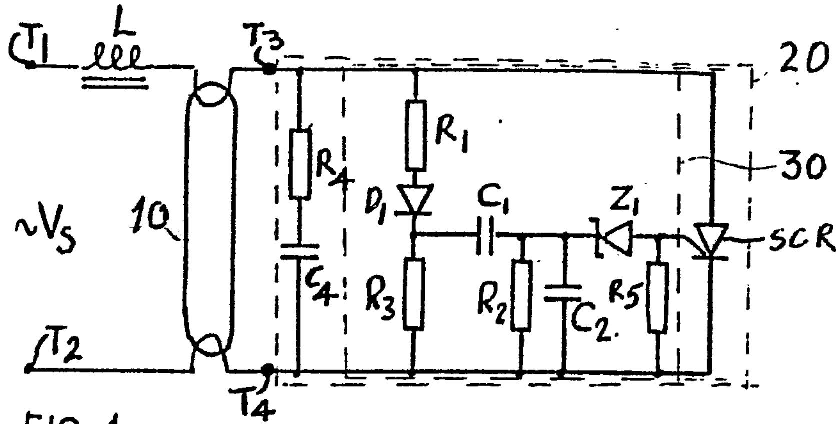

FIG 1

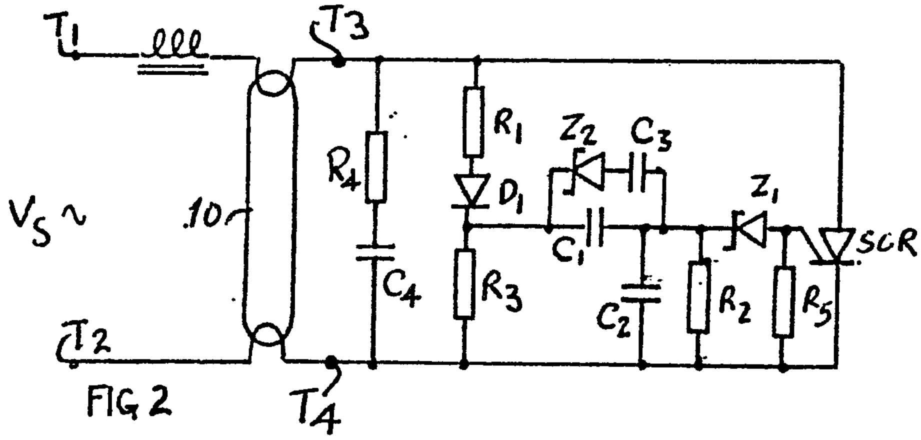

FIG 2

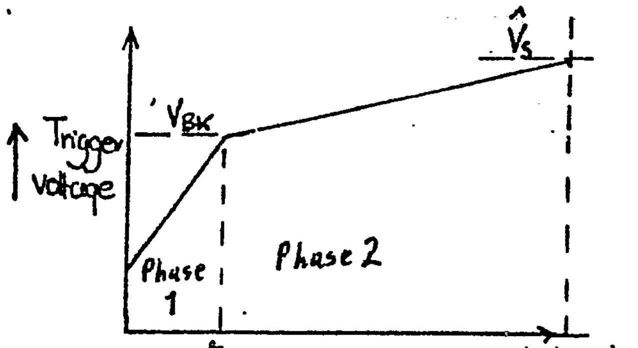

FIG3

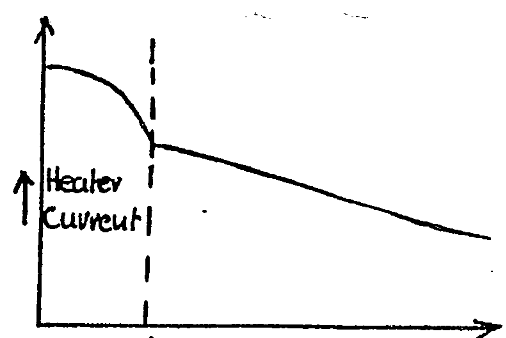

FIG4

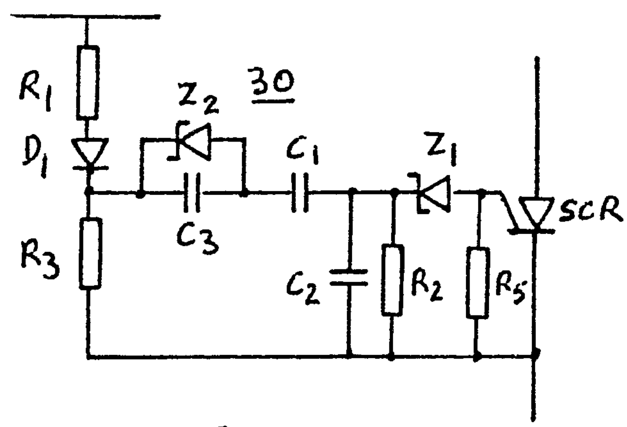
R1
D1
Z2
30
C1
Z1
SCR
C3
R3
C2
R2
R5

FIG 5

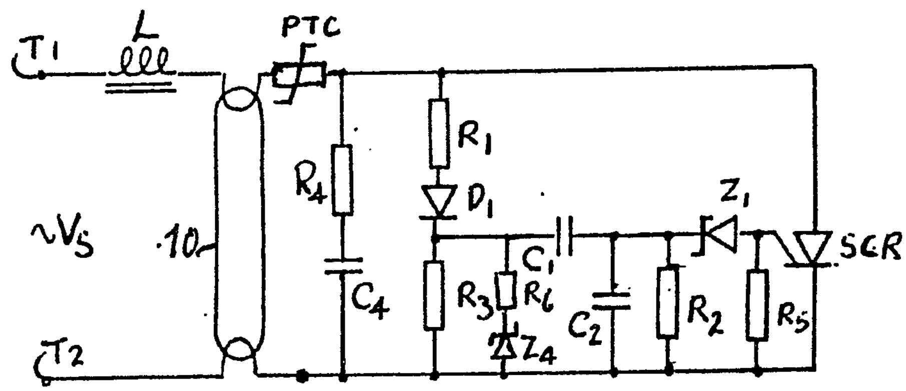
T1
L
PTC
R1
R4
D1
Z1
∿Vs
10
C1
SCR
C4
R3
R6
C2
R2
R5
Z4
T2

FIG 9

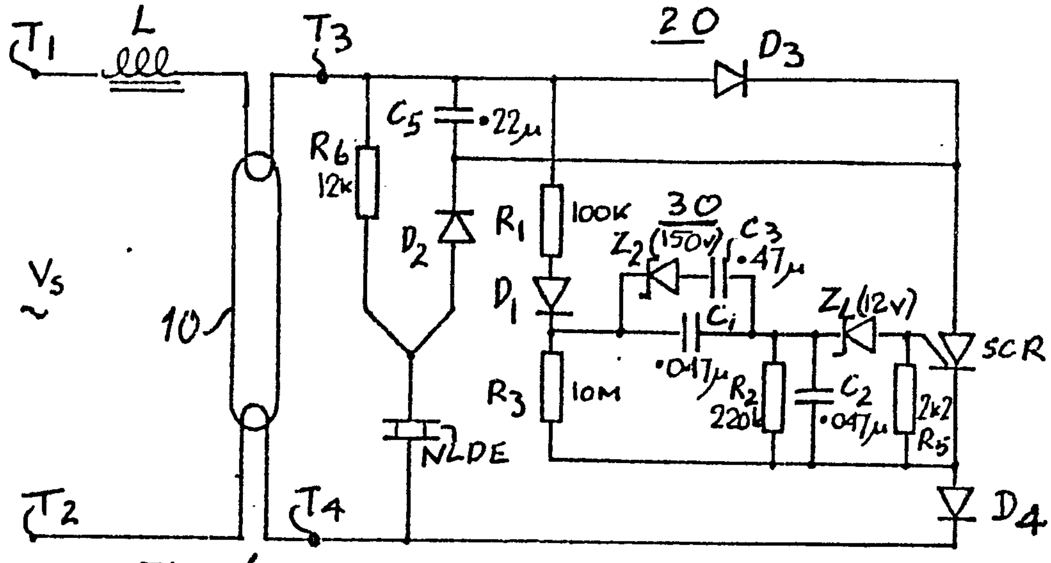

FIG. 6

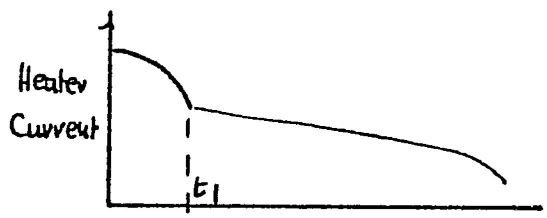

FIG.7A t →

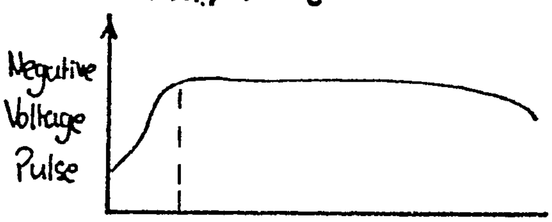

FIG.7B t1 t →

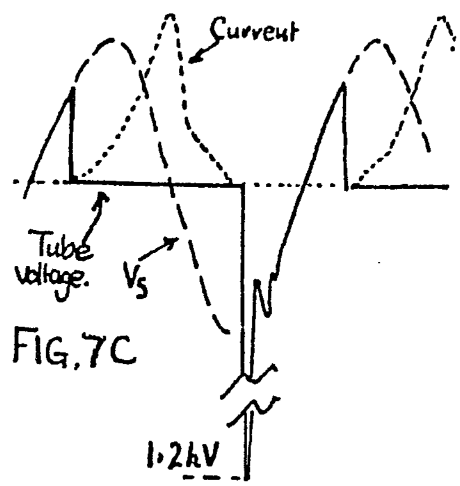

FIG.7C

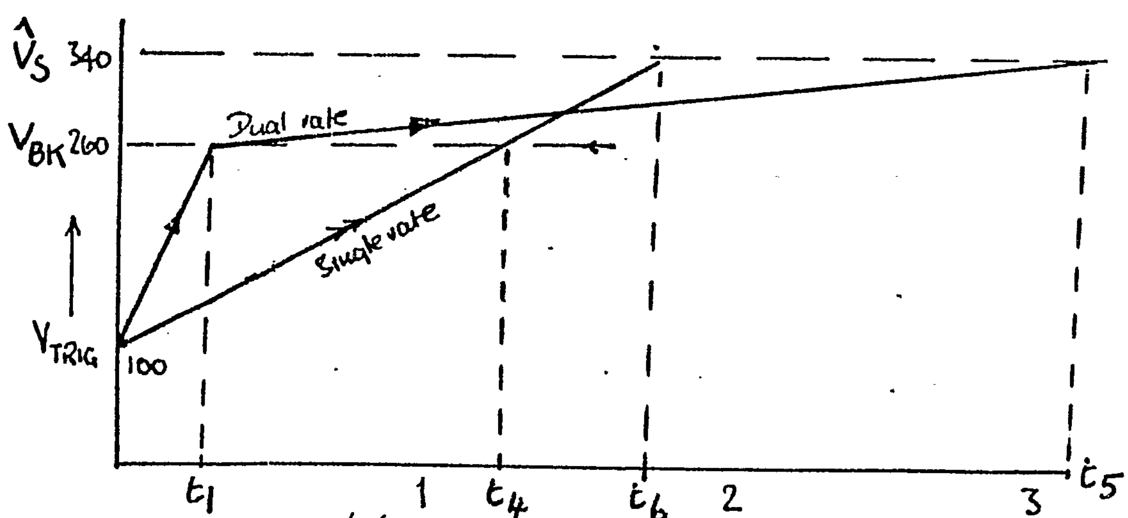

FIG.8

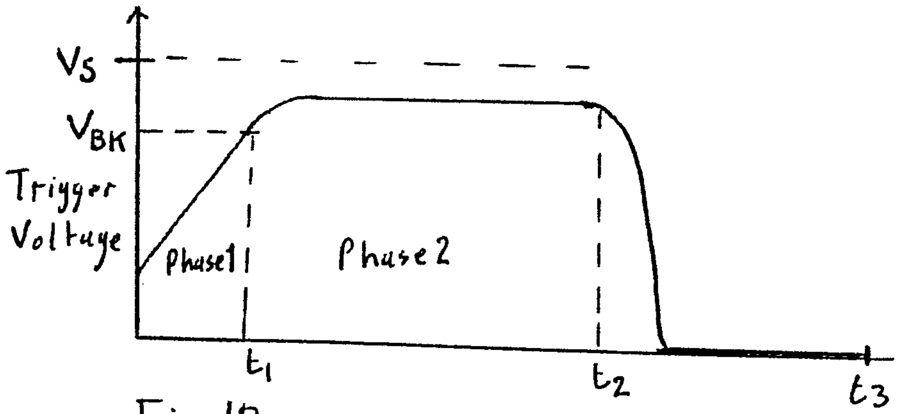
Vs
VBK
Trigger Voltage
Phase1
Phase2
t1
t2
t3

Fig.10

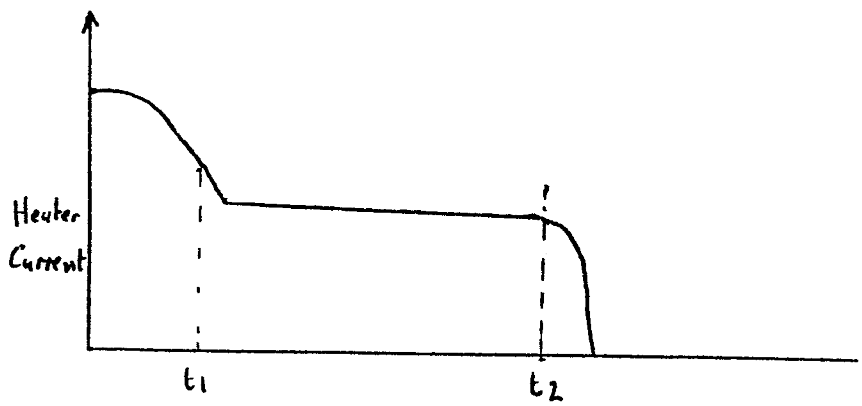
Heater Current
t1
t2

Fig.11