Aug. 25, 1953 T. E. FOULKE 2,650,278

GLOW TYPE THERMAL SWITCH

Filed Dec. 1, 1951

Fig. 1.

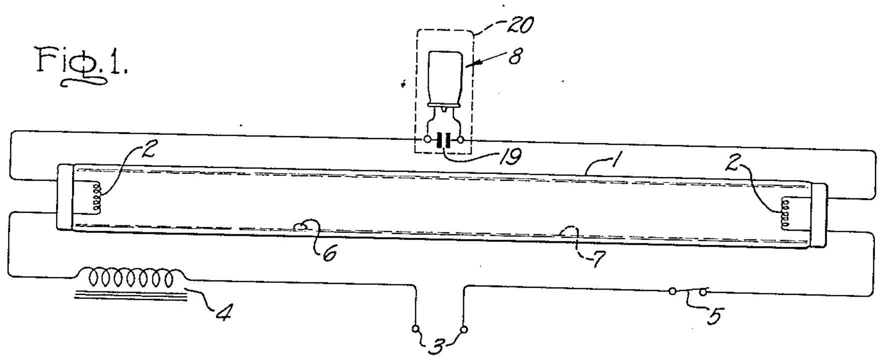
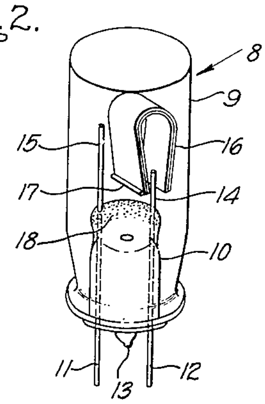


Fig. 2.



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GLOW TYPE THERMAL SWITCH

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11 Claims. (Cl. 200—113.5)

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The present invention relates to thermal switches, and in particular to switches comprising a thermally responsive element actuated by heat generated by a gaseous discharge.

Switches of this type have been in commercial use for many years for starting fluorescent electric discharge lamps having activated thermionic filamentary electrodes widely spaced in a tubular envelope and requiring preheating of the electrodes prior to starting of a discharge therebetween. The lamp circuit includes a ballast which also serves as an inductance and the switch is included in a preheat circuit for connecting the lamp electrodes in series and shunting the discharge path between them. In starting the lamp, sufficient voltage is applied to the switch to start a glow discharge therein which heats a thermally responsive bi-metallic element which serves as an electrode. The bi-metallic electrode is deformed by the heating and a contact part thereof moves toward and engages a stationary electrode in the switch. A higher heating current then flows through the lamp electrodes and the glow discharge is shorted out of the circuit. After a time sufficient to raise the temperature of the lamp electrodes to an electron emitting, main discharge supporting temperature, the bi-metallic electrode of the switch cools sufficiently to separate from the stationary electrode to open the switch contacts and break the heating circuit. A transient voltage surge or kick produced by the inductance in the lamp circuit on opening of the switch contacts is impressed across the lamp to start the main discharge between the lamp electrodes.

Such glow switches have a "dark effect," that is, the starting or breakdown voltage of the glow discharge in the switch is higher in the dark than in the light. This has been minimized to the extent that the switches now start the lamp under the designed conditions even when enclosed in a light opaque housing, for example, by including a radioactive material, such as uranium oxide, in the switch envelope. U. S. Patent No. 2,329,134, issued September 7, 1943, to Leo R. Peters and which is assigned to the assignee of the present application describes glow type thermal switches wherein the "dark effect" is minimized by the use of radio active material and wherein the effect of ambient temperature changes on the breakdown voltage of the switch over a predetermined range of ambient temperature is eliminated by providing between the stationary electrode and the thermally responsive electrode a fixed discharge gap smaller than the

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gap between the contact portions of said electrodes over said ambient temperature range.

Glow type thermal switches of the above type have been successfully used for many years for starting commercial fluorescent discharge lamps and commercial germicidal lamps containing a starting gas and mercury and of various sizes ranging from 6 to 100 watt. Recently, however, a highly efficient fluorescent lamp of 85 watt size and containing krypton as a starting gas has been made commercially available by the assignee of the present application as a replacement for a commercial 100 watt fluorescent lamp containing argon as a starting gas. The krypton starting gas lamp may be used in equipment designed for the argon starting gas lamp without change in the electrical elements of such equipment and has substantially the same light output as the 100 watt argon starting gas lamp because of its higher efficiency. However, starting difficulties have been encountered with the krypton lamp even though the starting voltage thereof, while higher than that of the argon lamp, is lower than the transient starting or kick voltage the inductance used in the equipment for the argon lamp is capable of supplying.

The cause of the starting difficulty with the krypton lamp used in equipment intended for an argon lamp has been found to be in the glow type thermal switches used in such equipment. An object of the present invention is, therefore, to provide a glow type thermal switch capable of starting a fluorescent lamp of either of the above types when used in equipment intended for a 100 watt argon starting gas lamp. Further objects and advantages attaching to the invention and to its use and operation will be apparent from the following detailed description of species thereof and from the appended claims.

I have discovered that the cause of the failure of the krypton lamp to start on opening of the glow switch contacts is dissipation in the switch of too large a part of the transient voltage surge produced by the inductance on opening of the switch contacts. Normally, a discharge takes place between the switch electrodes when the switch contacts open, but the voltage dissipated by such discharge is usually, and theoretically should be, less than that which would reduce the voltage surge produced by the inductance below that required to start the krypton lamp. I have discovered further that the abnormal dissipation of the starting voltage by the switch is caused by a higher conductivity of the ionized gaseous atmosphere between the switch electrodes than is normal with the gas filling of the switch. A feature of the invention is the provision of means in the switch to maintain the conductivity of the switch atmosphere at a value characteristic of the gas filling.

In the drawing accompanying and forming part of this specification, Fig. 1 is a general diagrammatic representation of wiring connections for an electric discharge lamp including the new glow type thermal switch, and Fig. 2 is a tilted or prospective view of the essential parts of the glow type thermal switch shown in Fig. 1.

Fig. 1 shows a fluorescent discharge lamp of the positive column electric discharge type with a tubular envelope 1 having the usual spaced-apart activated thermionic cathodes 2 in its ends which are specially heated cathodes of the usual coiled filament and alkaline earth oxide coated type, and are shown connected across the terminals 3 of a power supply. The lamp circuit includes the usual ballast 4, which also serves as a starting inductance, and the manual make-and-break control switch 5. The envelope 1 contains a low pressure atmosphere of starting gas, such as krypton, a quantity 6 of mercury exceeding the amount that will vaporize during operation of the lamp and an internal coating 7 of fluorescent material or phosphor on the inner surface of envelope wall. A starting and electrode-heating circuit is shown connected to a terminal of each of the filamentary cathodes 2, 2 and across the lamp, with a starting switch 8 included therein.

The general mode of operation in starting a lamp with this circuit arrangement is as described above, that is, when the switch 5 is closed to turn on the lamp the switch device 8 permits flow of curent through the circuit including the cathode filaments 2, 2 connected in series therein for a length of time sufficient to preheat the cathodes to an adequate emissive temperature to support a discharge therebetween, and then suddenly breaks the series connection between filaments 2 so that the resulting transient voltage surge or kick produced by the inductance 4 on breaking of the filament circuit is impressed across the space between the cathodes 2, 2 to initiate a discharge between them and start the lamp.

The switch 8 shown in detail in Fig. 2 of the drawing comprises a hermetically sealed glass envelope 9 having a reentrant stem 10 through which current leading-in wires 11 and 12 are hermetically fused or welded. The stem 10 is provided with an exhaust tube 13 through which the envelope 9 is exhausted of air and filled with the desired ionizable gaseous atmosphere during the manufacture of the switch. The inner end 14 of wire 12 and the inner end 15 of wire 11 are both of nickel or nickel-iron alloy and the thermally responsive electrode 16 is welded to wire end 14 which serves as its support. Said electrode 16 is bent over in a U-shape, as shown, so that the free end thereof is located between support 14 and wire end 15 which serves as an electrode. A refractory metal contact 17, such as a rod of molybdenum, is welded to the electrode 16 adjacent or at the free end thereof and on the surface thereof facing the electrode 15 which also serves as a contact of the switch. The upper portion of electrode 16 is closer than the contact 17 to the electrode 15 to eliminate the effects of ambient temperature changes on the breakdown voltage of the switch over a predetermined temperature range. The envelope 9 has an ionizable

gaseous atmosphere therein for conducting current between the switch electrodes 15 and 16.

The electrode 16 comprises two strips of metal having different coefficients of linear expansion securely fastened together, as by welding. The inner strip has a greater coefficient of expansion than the outer strip and the free end of the electrode 16 moves toward the electrode 15 with increasing temperature and away from the electrode 15 with decreasing temperature. The inner strip is made of a chrome-iron alloy and the outer strip of a nickel-iron alloy though it will be understood, of course, that other metals or alloys having the desired characteristics may be used, when desired. The electrode 16 and the contact 17 are coated with zinc after these elements are welded together and before they are mounted in the envelope 9.

The krypton starting gas fluorescent lamp shown in Fig. 1 is of the type disclosed and claimed in Patent No. 2,473,642, issued June 21, 1949, assigned to the assignee of the present application and wherein Clifton G. Found and Wilford J. Winninghoff are the inventors. In this lamp the pressure of the starting gas, krypton, is within the range of 7 to 12 mm. pressure and the wall loading on the envelope 1, that is, the energy or power dissipated per unit area of the envelope area, not including the losses at the electrodes 2, 2, is within the range of from 7 to 21 milliwatts per square centimeter, inclusive. In the 85 watt size the lamp envelope 1 is 60 inches long overall and has an outer diameter of 2⅛ inches.

In order to start the 85 watt lamp into operation reliably a transient voltage of at least 500 volts should be applied across the lamp electrodes 2, 2 by the inductance 4 on breaking of the contact between the electrodes 15 and 16 in the glow switch 8. I have found that the standard inductance 4 and the standard type of switch 8 successfully used heretofore in starting the commercial 100 watt argon filled lamp which requires a lower transient voltage, such as a voltage of about 350 volts, for starting may be used for starting the 85 watt krypton lamp and thus make possible the substitution of the latter lamp in existing equipment for the 100 watt argon lamp by providing a "getter" in the switch envelope 9 to keep the ionizable gaseous atmosphere in the switch free from gaseous substances of lower ionizing potential and by substituting another radioactive material for the uranium oxide used heretofore.

The use of a "getter" and radioactive material other than uranium oxide in the switch envelope 1 affects the conductivity of the ionizable gaseous atmosphere therein to the end that the dissipation in the switch of the transient or kick voltage produced by the inductance 4 is minimized and thus a higher voltage is impressed across the lamp for starting the latter. This is accomplished in accordance with my invention without increasing the breakdown voltage of the switch above that applied thereto in the circuit or increasing the time required for the switch contacts to close.

The pressure of the gas mixture in the switch is of importance because it has an effect on the dissipation by the switch of the transient or kick voltage produced by the inductance and on the time required for the switch contacts to close. Also the gas pressure has an influence on the time the switch contacts remain closed which determines the preheat time of the lamp electrodes 2. A range of preferred gas pressures for my new switch is disclosed below.

The correlation of these three features of my invention provides a glow switch capable of reliably starting an 85 watt krypton lamp or a 100 watt argon lamp by the same electrical equipment to the end that one lamp may be replaced by the other and the need for a special glow switch for use with each lamp is eliminated.

I have demonstrated that red phosphorus is an effective "getter" for use in the glow switch 8 and that thorium oxide is an effective radioactive material in place of uranium oxide for use with red phosphorus. I prefer to apply these materials mixed as a water paste to the pinch or press portion of the glass stem 10 as shown at 18 in the drawing. I have found that the junction between the electrode 15 of smaller area and the glass of stem 10 should be covered by the coating 18 and preferably also the junction between the metal support 14 and the glass stem 10. The portion of the stem press between and around the junctions of stem press and the electrode 15 and support 14 is also covered to assure an effective amount of radioactive material in the switch envelope 9.

The following table shows the effect of various mixtures of red phosphorus and thorium oxide, each mixture being used in a group of switches containing a mixture of neon mixed with ½% argon, by volume, at a pressure of 61 mm. at room temperature, on the transient or kick voltage produced across the lamp by the inductance 4 on opening of the switch contacts; on the change in the breakdown voltage of the switch in the dark and in the light, that is, on the "dark effect," and on the time required for the switch to close, that is, for contact 17 to engage electrode 15. In the table the values given are average values of each group of switches. The transient voltages are listed under the heading "Peak Volts" and the change in the "dark effect" under the heading "Dark BD (ΔV)." The other headings are believed to be self-explanatory, the symbol "P" representing red phosphorus.

Percent P, by vol.	Percent ThO_2, by vol.	Peak Volts	Dark BD (ΔV), volts	Switch Closing Time, Sec.
0	100	390	5	3
10	90	420	5	3.3
20	80	455	5	4.0
40	60	515	5	4.8
60	40	580	5	5.5
70	30	610	5	6.0
80	20	642	8.5	7.0
90	10	675	13.5	10.0
100	0	710	20.0	15.0

In view of the above data a mixture of ⅔ red phosphorus and ⅓ thorium oxide by volume, or 31% red phosphorus and 69% thorium oxide by weight, was selected as the optimum or most effective composition. The mixture is preferably ball milled for 24 hours with a small amount of water and is applied as a water paste to the stem 10 as described above.

The effect of different pressures of the neon-argon gas mixture described above on switches provided with the optimum composition of "getter" and radioactive material also described above is shown in the following table wherein the gas pressure in millimeters is listed under the heading "P, mm."; the time the switch contacts remain closed to preheat the lamp electrodes is listed under the heading "Preheat Time," and the time between the closing of the manual switch 5 and the application of the transient or kick voltage across the lamp is listed under the heading "Starting Time." The other headings have been explained above in connection with the preceding table.

P, m. m.	Peak Volts	Closing Time, sec.	Preheat Time, sec.	Starting, Time, sec.
40	710	7.5	1.6	9.1
50	660	6.5	2.1	8.6
60	605	5.5	2.7	8.2
70	555	4.3	3.2	7.5
80	500	3.3	3.8	7.1
90	450	2.2	8.5	10.7

From this data a gas pressure of 61 mm. at room temperature was selected as the optimum pressure for the mixture of neon with ½% argon.

A glow type thermal switch of the type shown in the drawing and provided with the optimum mixture of "getter" and radioactive material and with the gas filling at the optimum pressure described above has a breakdown voltage of approximately 120 volts even when enclosed in the usual light-opaque metal container indicated diagrammatically at 20 in Fig. 1 of the drawing, breaks the heating circuit so that the kick voltage of the inductance 4 is applied to the lamp for starting approximately 8 seconds after closing of the manual switch 5 in the lamp circuit and does not reduce the kick voltage of the inductance 4 below approximately 500 volts. Obviously such a switch is highly useful in circuits in which the power source has a voltage of 110 to 120 volts and with a secondary voltage of the ballast of 150 volts and in which the lamp requires a transient voltage of about 500 volts for starting.

The usual condenser for suppressing radio interference is shown at 19 in Fig. 1 of the drawing.

The chief cause of the difficulty with prior commercial switches of the above type, that is, the tendency of the switch to dissipate too much of the transient or kick voltage supplied by the inductance for starting the lamp, was due to the presence of alkali vapor in the gaseous atmosphere when the switch contacts opened and current passed. Inasmuch as such vapor has a much lower ionizing potential than the mixture of fixed gases employed, the conductivity of the gaseous atmosphere of the switch was markedly increased by the presence of such vapor to the end that the dissipation of the kick voltage by the switch was too high.

The source of the alkali metal vapor in such switches is the glass at the junction between the switch inleads and the glass stem press. The junction between the stem press and the inlead for the smaller area electrode 15 is the main source of the alkali and for some switches applying the red phosphorus to this junction only is effective for solving the problem. I prefer to cover both junctions, however, for the sake of assurance of results. When electrodes of substantially equal area are used the junctions of the stem press and the inleads for both electrodes should be covered by red phosphorus. In covering either one or both of said junctions the parts of the inleads and the stem press adjacent thereto should also be covered. By use of the present invention, alkali metal vapor in the switch atmosphere and the effects attendants on its presence in this atmosphere, has been eliminated.

The use of a "getter" with the usual uranium oxide used heretofore to eliminate the "dark effect" was found to be ineffective because the switch then dissipated as much of the kick voltage of the inductance as it did prior to the use of a getter therein. Thus, the uranium oxide had the effect of eliminating the highly advantageous result obtained by the use of the getter. In the course of my investigations I discovered that thorium oxide was effective for minimizing the "dark effect" in red phosphorus containing switches without destroying the beneficial effects of the getter provided the thorium oxide is present in an amount of approximately 65% by volume in the mixture of this oxide with the getter. A higher percentage of thorium oxide than 65% increases the dissipation by the switch of the kick voltage of the inductance to the point that the kick voltage is too low to start the lamp, as is apparent from the first of the above tables. A percentage of thorium oxide in the mixture of less than 20% by volume is not desirable because of the longer closing time of the switch and the higher breakdown voltage thereof in the dark as also shown by the first of the above tables.

While I have indicated above that a pressure of 61 mm. is used in the switch it will be understood that this pressure was arrived at as a compromise figure taking into consideration all the characteristics of the switch including that of the length of the useful life thereof. From the second table above it is apparent that the gas pressure may be within the range of 40 to 80 mm. without dissipating in the switch so much of the kick voltage of the inductance that the lamp will refuse to start on opening of the switch contacts. However, in view of the fact that the preheat time of the electrodes 2 of the lamp is 1.5 seconds minimum I prefer to utilize a gas pressure in the switch slightly in excess of 40 mm. Therefore, the gas pressure in the switch should be within a range of slightly more than 40 mm. and slightly less than 80 mm. and I prefer a gas pressure within the range of about 50 to 70 mm.

The term "getter" as used herein and in the appended claims will be understood as meaning a substance which combines with free alkali to form therewith compounds of greater stability and lower vapor pressure than alkali under the influence of a discharge in the switch.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A glow type thermal switch comprising a sealed envelope having a portion of alkali-containing glass, an ionizable gaseous atmosphere and electrodes in said envelope at least one of which is deformable by heat into engagement with the other electrode, and current inleads for said electrodes extending through the wall of said alkali-containing glass envelope portion, a getter for alkali in said envelope and covering the junction between said envelope portion and at least one of said inleads to keep the switch atmosphere free from alkali vapor, said getter comprising red phosphorus.

2. A glow type thermal switch comprising a sealed envelope of alkali-containing glass, an ionizable gaseous atmosphere and a pair of electrodes in said envelope one of which is of substantially smaller area than the other and the other of which is deformable by heat into engagement with the first named electrode, and current inleads for said electrodes extending through the wall of said envelope, a getter for alkali in said envelope and covering the junction between said envelope and the inlead for said

electrode of smaller area to keep the switch atmosphere free from alkali vapor, said getter comprising red phosphorus.

3. A glow type thermal switch comprising a sealed glass envelope provided with a reentrant stem of alkali-containing glass, an ionizable gaseous atmosphere and a pair of electrodes in said envelope at least one of which is deformable by heat into engagement with the other of said electrodes, and current inleads for said electrodes extending through said stem, a getter for alkali in said envelope and covering the junction between said inleads and said stem to keep the switch atmosphere free from alkali vapor, said getter comprising red phosphorus.

4. A glow type thermal switch comprising a sealed glass envelope provided with a reentrant stem of alkali-containing glass, containing an ionizable gaseous atmosphere and a pair of electrodes at least one of which is deformable by heat into engagement with the other electrode, and current inleads for said electrodes extending through said stem, a getter for alkali in said envelope and covering the junctions between said inleads and said stem to keep the switch atmosphere free from alkali vapor, and thorium oxide mixed with said getter, said getter comprising red phosphorus.

5. A glow type thermal switch comprising a sealed envelope having a portion of alkali-containing glass, an ionizable gaseous atmosphere and electrodes in said envelope at least one of which is deformable by heat into engagement with the other electrode, and current inleads for said electrodes extending through the wall of said alkali-containing glass envelope portion, a getter for alkali in said envelope and covering the junction between said envelope portion and at least one of said inleads to keep the switch atmosphere free from alkali vapor and thorium oxide in said switch to facilitate starting, said getter comprising red phosphorus.

6. A glow type thermal switch comprising a sealed envelope having a portion of alkali-containing glass, an ionizable gaseous atmosphere and electrodes in said envelope at least one of which is deformable by heat into engagement with the other electrode, and current inleads for said electrodes extending through the wall of said alkali-containing glass envelope portion, a mixture in said envelope of red phosphorus and thorium oxide in which the thorium oxide is present in the mixture in an amount of between about 20 and 65 per cent by volume, said mixture covering the junction between said envelope portion and at least one of said inleads.

7. A glow type thermal switch comprising a sealed envelope having a portion of alkali-containing glass, an ionizable gaseous atmosphere and electrodes in said envelope at least one of which is deformable by heat into engagement with the other electrode, and current inleads for said electrodes extending through the wall of said alkali-containing glass envelope portion, a mixture in said envelope of red phosphorus and thorium oxide in which the thorium oxide is present in the mixture in an amount of about 69 per cent by weight, said mixture covering the junction between said envelope portion and at least one of said inleads.

8. A glow type thermal switch comprising a sealed envelope having a portion of alkali-containing glass, an ionizable gaseous atmosphere and electrodes in said envelope at least one of which is deformable by heat into engagement

with the other electrode, and current inleads for said electrodes extending through the wall of said alkali-containing glass envelope portion, a getter for alkali in said envelope and covering the junction between said envelope portion and at least one of said inleads to keep the switch atmosphere free from alkali vapor, the pressure of said gas being within a range of slightly more than 40 mm. and slightly less than 80 mm., said getter comprising red phosphorus.

9. A glow type thermal switch comprising a sealed envelope having a portion of alkali-containing glass, an ionizable gaseous atmosphere and electrodes in said envelope at least one of which is deformable by heat into engagement with the other electrode, and current inleads for said electrodes extending through the wall of said alkali-containing glass envelope portion, a getter for alkali in said envelope and covering the junction between said envelope portion and at least one of said inleads to keep the switch atmosphere free from alkali vapor, the pressure of said gas being within the range of about 50 to 70 mm., said getter comprising red phosphorus.

10. A glow type thermal switch comprising a sealed envelope of glass having an alkali component, said envelope containing a mixture of neon and ½ per cent of argon at a pressure of about 61 mm. and normally spaced cooperating electrodes including a stationary electrode and a thermally responsive electrode adapted to engage said stationary electrode when heated by a discharge between said electrodes and thus to extinguish said discharge and to return to its spaced position with respect to said stationary electrode on cooling to break the direct electrical connection between said electrodes, inlead support wires for said electrodes passing through juxtaposed portions of said envelope and a coating of red phosphorus on the parts of said inleads and said envelope at and adjacent the junctions therebetween to combine with any free alkali freed from the glass and form therewith compounds of greater stability and lower vapor pressure under the influence of a discharge between said electrodes whereby to maintain the electrical conductivity of the switch atmosphere between said electrodes at a value characteristic of the said mixture of gases.

11. A glow type thermal switch comprising a sealed envelope of glass having an alkali component, said envelope containing a mixture of neon and ½ per cent of argon at a pressure of about 61 mm. and normally spaced cooperating electrodes including a stationary electrode and a thermally responsive electrode adapted to engage said stationary electrode when heated by a discharge between said electrodes and thus to extinguish said discharge and to return to its spaced position with respect to said stationary electrode on cooling to break the direct electrical connection between said electrodes, inlead support wires for said electrodes passing through juxtaposed portions of said envelope and a coating of red phosphorus on the parts of said inleads and said envelope at and adjacent the junctions therebetween to combine with any free alkali freed from the glass and form therewith compounds of greater stability and lower vapor pressure under the influence of a discharge between said electrodes whereby to maintain the electrical conductivity of the switch atmosphere between said electrodes at a value characteristic of the said mixture of gases and thorium oxide mixed with said red phosphorus in an amount of about 69 per cent of the mixture by weight.

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