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(54) ELECTRIC SWITCH

(71) We, PONDER & BEST, INC. a corporation organized under the laws of the State of California, United States of America, of 1630 Stewart Avenue, Santa Monica, State of California, United States of America, (formerly of 11201 West Pico Boulevard, Los Angeles, California 90064), do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electric switches. It will be described in the context of electronic photoflash devices in which the invention arose, but switches embodying the invention are also expected to be useful in other applications.

According to the invention there is provided an electric switch comprising a pair of electrically conductive contacts, and at least one coil of a mechanically resilient, electrically conductive material connected to and supporting one of said contacts and formed as a compression spring normally urging said one of said contacts against the other one of said contacts, said coil and said contacts being arranged to conduct a current, and said coil being formed to act as a solenoid magnetically attracting said one contact with a force dependent on the current flowing therethrough and to produce a mechanical spring force of a value such that it is overcome by the electromagnetic attraction force produced by a current whose amplitude exceeds a predetermined value, whereupon said one contact is drawn away from said other contact. Thus, such a switch inherently responds to an increase in the amplitude of the current flowing therethrough above a predetermined value to create an open circuit.

Advantages of the invention and further details of such switches will become apparent [Price 25p]

rent from the following description, given by way of example and with reference to the accompanying drawings in which:—

Fig. 1 is a block diagram of an electronic photoflash unit or device.

Fig. 2 is a diagram illustrating the operation of the circuit of Fig. 1 in comparison with the operation of prior art circuits.

Fig. 3 is a simplified circuit diagram of a modified form of the unit of Fig. 1 which includes an electric switch embodying the present invention.

Fig. 4 is a perspective cross-sectional view of one form of the said electric switch in the photoflash unit of Fig. 3.

The electronic photoflash device or unit whose circuit is illustrated by Fig. 1 employs, as is usual, an electronic photoflash tube 3 and an energy storage capacitor 1, but represents an improvement over known circuits in that it employs a combination of a parallel type circuit which determines the accuracy of the light control and a series type circuit which performs the actual function of interrupting the discharge of the photoflash energy storage capacitor.

The circuit of Figure 1 includes, in addition to an energy storage capacitor 1 and a flash tube 3, a trigger circuit 33 controlled by the closing of the camera synchronizing contact to trigger a light flash, a parallel type light flash control circuit 81 and a series type control element 82 which functions, and is illustrated, as a normally closed electronic switch. Series type circuit 82 is connected so that the electronic switch which it represents is in series in the line between capacitor 1 and tube 3. Circuit 81 is composed essentially of a light sensor 80, an electronic gate 83 connected to activate the circuit 81 upon the commencement of a light flash, an integrator-comparator circuit 84 and a circuit 85 which functions as a normally open electronic switch connected in parallel with the tube 3. Both electronic

switches 85 and 82 are connected to be operated by an output signal from circuit 84.

Circuit 81 could be constituted by any of the previously disclosed parallel circuits, e.g. the circuit 30 of Fig. 3 of our patent specification No. 1,267,234, in which case element 85 would be constituted by the element 204 of Fig. 2 of that specification. Similarly circuit 82 could be constituted by an element such as switch 103 illustrated in Figure 1 of that specification, which element could be a gate turn-off thyristor or other equivalent component.

The operation of the system of Figure 1 is as follows: The voltage due to the charge across capacitor 1 is applied across photoflash tube 3 via the normally closed electronic switch 82. When the camera synchronizing contact is closed to initiate a flash, triggering circuit 33 produces a pulse to trigger the production of a light flash by tube 3. The leading edge of the current pulse then passing through tube 3 produces a corresponding current pulse which passes through gate circuit 83 to initiate operation of integrator-comparator circuit 84. The light reflected from the subject being photographed reaches sensor 80 and is converted into a proportional electrical signal which is processed by circuit 84. When the total quantity of light received by sensor 80 reaches a predetermined value, the output signal from circuit 84 reaches a level at which it actuates switches 85 and 82. This actuation closes switch 85 so as to create an effective short circuit across the photoflash tube 3 and thus halt the production of light by that tube. At the same time, the actuation of switch 82 serves to open that switch and thus halt the discharge of capacitor 1.

The switch 82 is so designed that it will reclose only after a delay period which is longer than the period required for deionization of tube 3 and the opening of switch 85.

Figure 2 illustrates the operation of the circuit of Figure 1 in comparison with the operation of prior circuits. The A curves represent the intensity of the light produced by tube 3, while the B curves represent the voltage across capacitor 1. A light flash is initiated at the moment T_0 , while the moment at which the predetermined quantity of light has been received by sensor 80 is T_1 . The time required for the circuit 81 to respond by closing switch 85 is ΔT_1 , and the time required for the circuit 81 to open switch 82 is ΔT_2 . The period ΔT_2 is normally longer than ΔT_1 , owing to the nature of components acting as normally closed electronic switches. However, because it is the closing of switch 85, which occurs with a delay of ΔT_1 , that determines the termination of the light flash, the longer delay

involved in the closing of switch 82 will not introduce any inaccuracies into the automatic flash limiting operation. However, the utilization of series switch 82 does result in a substantial energy saving in that it serves a large portion of the charge present on capacitor 1 and thus reduces the amount of energy, and the time, required to restore capacitor 1 to full charge. Curves A₁ and B₁ illustrate the operation of a conventional photoflash unit without any automatic flash limiting control. Curve B₂ illustrates the variation in the voltage across capacitor 1 in an automatic control circuit equipped only with a normally open flash limiting switch. This curve shows that with such a circuit, capacitor 1 is completely discharged after each light flash and must therefore be completely recharged before another light flash can be produced. Finally, curve B illustrates the variation in the voltage across capacitor 1 in the circuit shown in Figure 1, wherein capacitor 1 retains a substantial portion of its initial charge after a light flash has been terminated.

The curves of Figure 2 illustrate, in particular, that the quantity of light produced by the flash, illustrated by area C, is accurately controlled by the operation of switch 85, and that even though switch 82 does not open until after a delay of ΔT_2 , the quantity of the charge remaining on capacitor 1 after the opening of switch 82 is still relatively high. Thus, the device consumes only a small amount of energy in addition to that required for producing the desired light flash.

Figure 3 illustrates a specific embodiment of the circuit illustrated in block form in Figure 1, but modified in that there is no control connection from circuit 84 to switch 82. In Figure 3, the circuit for triggering tube 3 is not illustrated for purposes of simplicity. The parallel type circuit 81 is similar to circuits of the type illustrated in our patent specification No. 1,267,234 and operates in a manner disclosed in that specification.

The series type circuit 82' comprises a new type of electrodynamic switch which is connected in series between capacitor 1 and tube 3. This switch comprises a pair of contacts 87 which are maintained normally closed by the pressure of two compression springs 86. These springs are in the form of solenoids and serve simultaneously as induction coils. Contacts 87 and springs 86 are preferably disposed on a common axis. A capacitor 88 is connected in parallel with the contacts 87.

The operation of the circuit is as follows: Circuit 81 operates in the manner disclosed above in connection with the corresponding circuit of Figure 1. The series circuit 82' remains closed for as long as the intensity

of the discharge current from capacitor 1 is equal to the current required for maintaining tube 3 conductive. As soon as the switch 85 of parallel circuit 81 closes to place a short circuit across tube 3, the discharge current from capacitor 1 increases, as indicated by the steep portion of curve B of Figure 2, to a value which provokes sufficient electrodynamic forces in coils 86 to separate contacts 87 from one another, thus interrupting the discharge of capacitor 1. Capacitor 88 serves to absorb the arc which would normally appear between contacts 87 upon their opening and to then prolong the passage of current through the series circuit, the total result being a rapid opening of contacts 87 and a sufficiently long delay prior to their reclosing.

Each coil 86 acts as a solenoid and its connected contact 87 acts as a movable relay contact in that the current through coil 86 produces an axial magnetic field which attracts contact 87, the contact being of a magnetic material.

The nature of circuit 82' is such as to render unnecessary the provision of a control connection between that circuit and circuit 84.

Turning now to Figure 4, there is shown the physical structure of one form of the switch 82' illustrated in circuit form in Figure 3. The contacts 87 and solenoid-inductance coils 86 are preferably disposed in a hermetically sealed enclosure 123 whose interior 126 is either evacuated or filled with a gas, dielectric liquid, etc.

While such switches have been described in the context of electronic photoflash, they are also expected to be useful in other applications, particularly in other circuits for controlling the discharge of an energy storage capacitor.

Reference is directed to our copending application No. 39704/71 Serial No. 1,374,245.

WHAT WE CLAIM IS:—

1. An electric switch comprising a pair of electrically conductive contacts, and at least one coil of a mechanically resilient, electrically conductive material connected to and supporting one of said contacts and formed as a compression spring normally urging said one of said contacts against the

other one of said contacts, said coil and said contacts being arranged to conduct a current, and said coil being formed to act as a solenoid magnetically attracting said one contact with a force dependent on the current flowing therethrough and to produce a mechanical spring force of a value such that it is overcome by the electromagnetic attraction force produced by a current whose amplitude exceeds a predetermined value, whereupon said one contact is drawn away from said other contact.

2. A switch as claimed in claim 1 including two such coils each connected to and supporting a respective one of said contacts and each arranged to subject its respective contact to an electromagnetic attraction force.

3. A switch as claimed in claim 2 wherein said contacts and said coils are disposed on a common axis of the coils.

4. A switch as claimed in any of claims 1-3 wherein said contacts and the coil or coils are in a hermetically sealed enclosure.

5. A switch as claimed in claim 4 wherein the interior of the enclosure is evacuated or is filled with a gas or a dielectric liquid.

6. An electric switch as claimed in any of claims 1-5 including a capacitor connected between said contacts.

7. An electric switch as claimed in claim 1 substantially as herein described with reference to Fig. 3 or Fig. 4 of the accompanying drawings.

8. An electric circuit for controlling the discharge of an energy storage capacitor, including an electric switch as claimed in any of the preceding claims connected in series with the capacitor to open the discharge circuit in response to current flow therein exceeding a predetermined value.

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The nature of circuit 82' is such as to render unnecessary the provision of a control connection between that circuit and circuit 84.

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