June 11, 1968 J. MISENCIK ET AL 3,388,295

CURRENT INTERRUPTER

Filed Aug. 20, 1965 2 Sheets-Sheet 1

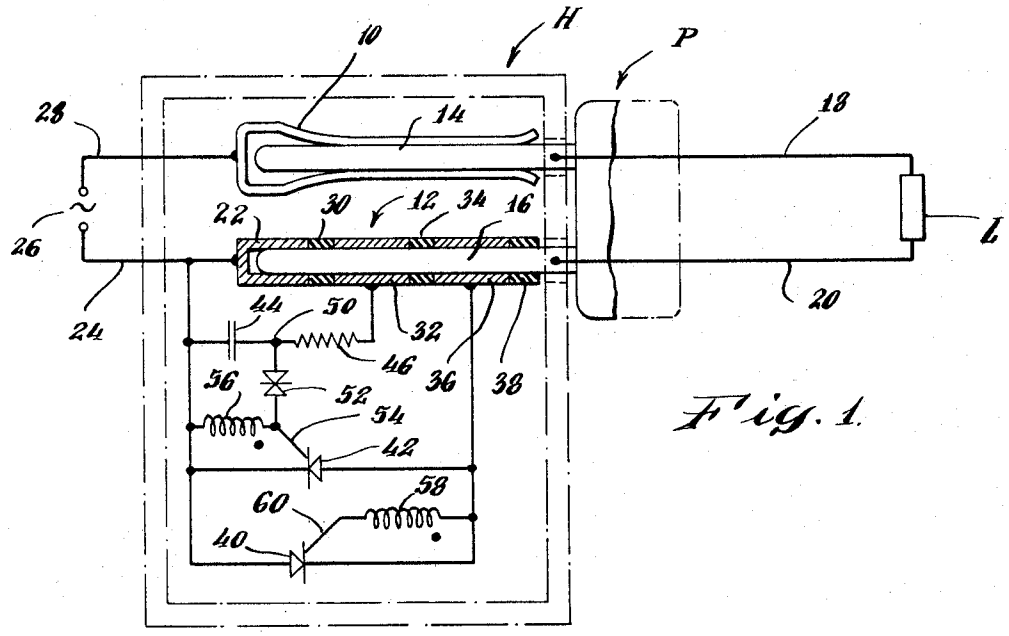


Fig. 1.

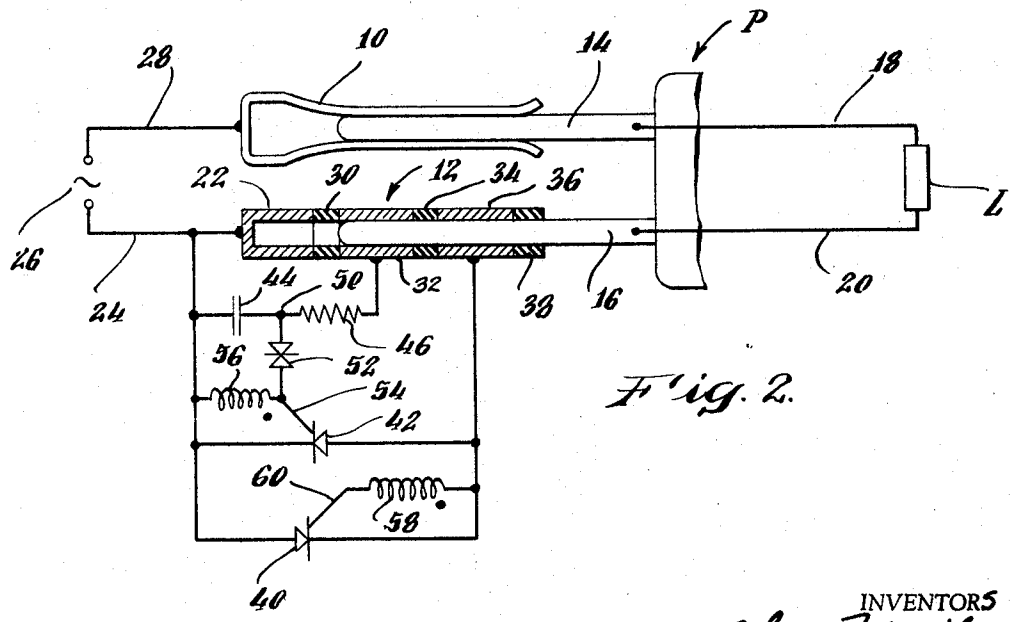


Fig. 2.

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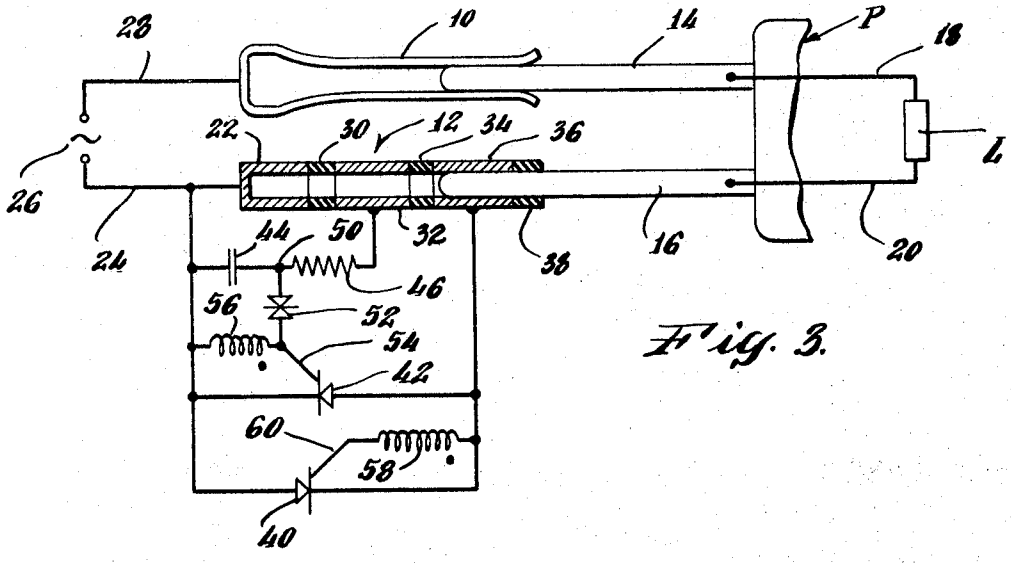


Fig. 3.

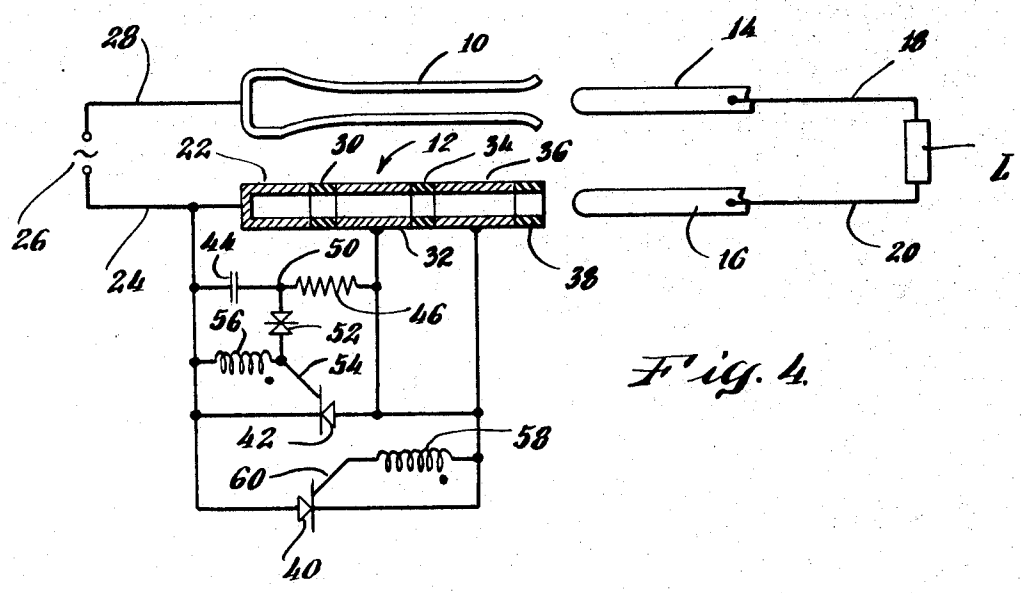


Fig. 4.

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CURRENT INTERRUPTER

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ABSTRACT OF THE DISCLOSURE

A load current interrupter having reduced arcing characteristics. A movable current carrying member is designed to sequentially engage and disengage from three conductive elements which are normally insulated from one another but are electrically interconnected by the movable member when it is fully engaged. A semiconductor switch is connected to carry load current between two of the conductive elements when the movable member is disengaged from the third. One of these two conductive elements is connected to a triggering circuit which "closes" and "opens" the switch.

This invention relates to a current interrupter and, more particularly, to such an interrupter which substantially reduces voltage transients and arcing upon making or breaking an electrical circuit.

Voltage transients and arcing are problems which are ever present in the making or breaking of electrical circuits. A number of techniques and devices have been employed in prior art apparatus for reducing these problems. These include arcing contacts, arcing horns, oil submergence, and various types of barriers, arc chutes, quenchers, and deionizing chambers. While such devices are effective for relatively high voltage, high current applications, they are not generally suitable for use in low power applications. Furthermore, these devices are bulky and expensive and do not reduce either the voltage transients or the arcing to satisfactorily low levels.

Accordingly, it is the primary object of the present invention to provide an improved current interrupter. Other objects are to provide such an interrupter which is small, inexpensive, and particularly well suited for use in low power devices.

The manner in which these objects are achieved will be more apparent from the following description, the appended claims and the figures of the attached drawings wherein:

FIG. 1 is a schematic illustration of a receptacle embodying the present invention, showing the blades of a male connector plug fully inserted therein;

FIG. 2 is an illustration similar to FIG. 1, showing the plug partially withdrawn;

FIG. 3 is an illustration similar to FIGS. 1 and 2 showing the plug in the last stage of withdrawal; and

FIG. 4 is an illustration similar to FIGS. 1–3 illustrating the plug in the withdrawn condition.

The objects of the invention are achieved by means of a load current interrupter which includes a semiconductor control element having first and second terminals connectable in the load circuit. The control element is normally non-conductive but may be rendered conductive in at least one direction by a trigger signal. A triggering circuit is energizable from a third terminal to apply such a trigger signal to the control element. Load current carrying means is connectable to all of said first, second, and third terminals and is sequentially disengageable from at least the first and third terminals.

With particular reference to FIG. 1, the various elements of the invention are schematically shown as enclosed within the housing H of an electrical outlet. Mounted within the housing is a female contact **10** which may be of the standard spring type for receiving the prong of an electrical plug. Mounted alongside the contact **10** is a special female contact **12**. The contacts **10**, **12** are arranged to receive the blades **14**, **16**, which extend from an electrical plug P through suitable slots or openings in the housing H. The blades of plug P are connected to an electrical load L by means of conductors **18**, **20**. The special female contact **12** is formed of electrically conductive segments which are insulated from one another. Although the contact **12** may have various configurations, it is illustrated as forming an elongated box of rectangular cross section for slidably receiving the blade **16**. The inner end segment **22** is connected by means of conductor **24** to one side of a standard power source **26**, the other side of the power source being connected to the contact **10** by conductor **28**. An insulating spacer **30** separates the inner end segment **22** from a conductive central segment **32**. Central segment **32**, in turn is separated by an insulating spacer **34** from an outer segment **36**. In the disclosed embodiment, an outer insulator **38** is provided on the end of the outer segment **36**. However, this is not a necessary feature of the invention and may be omitted.

A pair of silicon controlled rectifiers **40**, **42** are connected in parallel between the outer segment **36** and the inner end segment **22** with their anode-cathode circuits in reversed polarity. The central segment **32** is electrically connected to the end segment **22** by means of a series circuit comprising a capacitor **44** and a resistor **46**. The interconnection **50** between the capacitor **44** and resistor **46** is coupled, by means of a breakover diode **52**, to the gate **54** of silicon controlled rectifier **42**. The primary winding **56** of a pulse transformer is connected between the gate **54** and the inner end segment **22**. The secondary winding **58** of the pulse transformer is connected between the gate **60** of silicon controlled rectifier **40** and the outer segment **36**. It will be noted that the polarities of the primary and secondary windings of the pulse transformer are reversed, relative to their corresponding silicon controlled rectifiers, as indicated by the polarity marking associated with each winding.

Operation

The operation of the invention may be best understood by observing the sequence illustrated successively by FIGS. 1–4. Beginning with FIG. 1, plug P is shown with its blades completely inserted into contacts **10**, **12**. Under these conditions, it will be noted that a direct connection exists from the power source **26** to the load L. In the case of blade **14**, this connection is made along the entire contact portion of the contact **10**. In the case of blade **16**, the connection is made solely with the inner end segment **22**. It will also be noted that the various portions of the electronic circuit are shorted out by the blade **16** which electrically interconnects all of segments **22**, **32**, and **36**.

When the circuit is as shown in FIG. 1, the electrical resistance between segment **22** and segment **32** is essentially zero because of the short-circuiting action of conductive blade **16**. Assume, now, that plug P is withdrawn to the position shown in FIG. 2. When the blade **16** starts to leave segment **22**, the electrical resistance between segment **22** and blade **16** (and, in turn, segment **32**) starts to increase (air gap resistance). This air gap resistance will be in series with the load and current will flow through this gap resistance causing an arc to be drawn and a difference in potential will appear between segments **22** and **32**. Normally, an arc would exist as long as the voltage/distance relationship across the gap

is sufficient to sustain it. However, in this system, the arc will be quenched by the described circuitry.

Capacitor 44 and resistor 46, which are connected in series, will be across the potential difference which exists between segments 22 and 32. The capacitor 44 is selected to have relatively high capacitive reactance at the power source frequency. This frequency would most commonly be sixty cycles per second in the United States. The current supplied by the power source to the load now passes through the RC circuit of resistor 46 and capacitor 44, as well as through the air gap resistance existing between segment 22 and segment 32. As there is a small current flowing through the RC circuit, the voltage across capacitor 44 starts to increase. The breakover diode 52 and transformer primary 56 are connected in series across capacitor 44. The voltage across capacitor 44 increases until it reaches the breakover voltage of diode 52. Diode 52 then goes into a low impedance conducting state, allowing the capacitor to discharge a pulse of current through the transformer primary 56 and through the gate 54 to the cathode of silicon controlled rectifier 42. The resulting pulse in primary winding 56 induces a similar pulse across the secondary winding 58, and a pulse of current flows through the gate 60-cathode circuit of silicon controlled rectifier 40. If the polarities are such that the anode of rectifier 42 is positive with respect to its cathode, the gate to cathode current causes this rectifier to conduct. Rectifier 40 will not conduct as its anode to cathode polarity is not correct for conduction. During the next half cycle, rectifier 42 will not be able to conduct but the gate to cathode current through rectifier 40 will allow rectifier 40 to go into conduction. To appreciate the amount of arc-reduction achieved with this system, it must be understood that the time involved from blade 16 leaving segment 22 until a silicon controlled rectifier goes into conduction is on the order of microseconds. Therefore, blade 16 and segment 22 are actually breaking the load current for an infinitesimally small time, substantially reducing the arcing.

As the plug P is retracted to the position shown in FIG. 3, the blade 16 breaks contact with the central segment 32. This entirely stops the gate current to the rectifiers. One of the rectifiers, however, will be conducting unless the instantaneous voltage of the power source is at zero or if the voltage at 50 has not yet built to its "breakover" value. This rectifier will continue to conduct for the remainder of the half cycle. As soon as the supply voltage reverses, both rectifiers will be in the blocking condition as no gate current is received. In effect, therefore, the circuit serves to switch off the load current when the prong 16 is in the position illustrated in FIG. 3. For maximum arc suppressive effect, the plug should remain in the position illustrated by FIG. 3 for a time period equal to one half cycle at the supply frequency ($\frac{1}{120}$ sec. at 60 c.p.s.). If desired, this time lag may be introduced by a suitable mechanical stop or other means. Further withdrawal of the plug to the withdrawn position shown in FIG. 4 can thus create no arcing or transients because it is being removed from a deenergized contact.

The reverse operation is also accompanied by arc suppression, as will be readily apparent to one skilled in the art. For example, as the blades are reinserted, there will be no current flow until blade 16 makes contact with the central segment 32. This permits the relatively low gating current to flow and activate the silicon controlled rectifiers to permit load currrent to flow between outer segment 36 and source 26. When the blade 16 reaches the inner end segment 22, it effectively shorts out the gate circuit so that load current is carried directly from blade 16 to segment 22.

The values of the various circuit elements may be varied to suit the particular application. However, one arrangement which has been successfully employed utilizes: a 1:1 pulse transformer having fifty turns on each of the primary 56 and secondary 58; a .15 microfarad capacitor 44; a 5000 ohm resistor 46; a 32 volt breakover diode 52; and two silicon controlled rectifiers 40, 42, each rated at 200 P.I.V. 8 amperes RMS, and 100 amperes surge current.

It will be apparent to those skilled in the art that all the objectives set forth above are achieved by this invention. It will also be apparent that a number of variations and modifications may be made in this invention without departing from its spirit and scope. For example, the circuit has wide applicability to other circuit breaking devices, such as switches. In this regard, it will be noted that the functioning of the circuit will be the same, even if conductor 18 is connected directly to conductor 28 rather than through a separable connector. This would be equivalent to a switch or circuit breaker. It will also be seen that the position of segments 32, 36 may be reversed relative to the blade 16. Load current would then be broken by withdrawing the blade from the central segment.

As a further variation, other types of controlled semiconductor devices may be employed. These would include, for example, five layer devices triggered by various circuit arrangements, such as resistive circuits.

Accordingly, the foregoing description is to be construed as illustrative only rather than limiting. This invention is limited only by the scope of the following claims.

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

1. A current interrupter for an electrical load circuit which comprises: a semiconductor control element having first and second terminals connectable in said load circuit, said control element normally being substantially non-conductive but adapted to be rendered conductive in at least one direction by a trigger signal; triggering circuit means energizable from a third terminal to apply said trigger signal to said control element; and load current carrying means connectable to all of said first, second, and third terminals and sequentially disengageable from at least said first and third terminals.

2. A current interrupter for an electrical circuit between a power supply and a load which comprises: a first circuit member including a plurality of electrically conductive segments electrically insulated from one another, a first of said segments being connected in said circuit; a semiconductor control element connected between the first and a second of said segments to carry load current from said power supply to said load while bypassing a third of said segments, said control element normally being substantially non-conductive but adapted to be rendered conductive in at least one direction by a trigger signal; triggering circuit means energizable from said third segment to apply said trigger signal to said control element; and a second circuit member sequentially connectable to said segments to complete the load circuit, said second and third segments being electrically connected by said second circuit member when said second circuit member is in contact with said first segment.

3. The interrupter of claim 2 wherein said third segment is intermediate said first and second segments.

4. The interrupter of claim 2 wherein said semiconductor control element is a solid state controlled rectifier.

5. The interrupter of claim 4 wherein said rectifier is a silicon controlled rectifier.

6. A current interrupter for an electrical load circuit which comprises: a first circuit member including a plurality of electrically conductive segments electrically insulated from one another, at least a first of said segments connected in said load circuit; first and second semiconductor control elements connected in parallel and reversed polarity to carry load current between a first and a second of said segments, each of said control elements normally being substantially non-conductive but adapted to be rendered conductive in at least one direction by a trigger signal; triggering circuit means energizable from a third of

said segments to apply said trigger signal to each of said control elements; and a second circuit member sequentially connectable to said segments to complete the load circuit, said second and third segments being electrically connected by said second circuit member when said second circuit member is in contact with said first segment.

7. The interrupter of claim 6 wherein said third segment is intermediate said first and second segments.

8. The interrupter of claim 6 wherein said semiconductor control element is a silicon controlled rectifier.

9. A current interrupter for an electrical load circuit which comprises: a first circuit member including a plurality of electrically conductive segments electrically insulated from one another, at least a first of said segments being connected in said load circuit; solid state switching means including an anode, a cathode and a gate having its anode and cathode connected to carry load current between said first segment and a second segment; triggering means electrically interconnecting said gate and a third segment; and a second circuit member sequentially connectable to said segments to complete the load circuit, said second and third segments being electrically connected by said second circuit member when said second circuit member is in contact with said first segment.

10. The interrupter of claim 9 wherein said triggering means comprises: a capacitor and a resistor connected in series between said first and third segments; and a breakover diode connected between the interconnection of said capacitor and resistor and said gate.

11. A current interrupter for an electrical load circuit which comprises: a first circuit member including a plurality of electrically conductive segments electrically insulated from one another, at least a first of said segments being connected in said load circuit; first and second solid state switching means, each including an anode, a cathode, and a gate, the anode-cathode circuits being connected in parallel, reversed relationship to carry load current between said first segment and a second segment; triggering circuit means interconnecting the gate of each switching means with a third segment; and a second circuit member sequentially connectable to said segments to complete the load circuit, said second and third segments being electrically connected by said second circuit member when said second circuit member is in contact with said first segment.

12. The interrupter of claim 11 wherein said triggering means comprises: a capacitor and a resistor connected in series between said first and third segments; a breakover diode connected between the gate of said first switching means and the interconnection of said capacitor and resistor; a primary transformer winding across the gate and cathode of said first switching means; and a secondary transformer winding across the gate and cathode of said second switching means.

13. An electrical outlet for receiving the blades of a connector plug therein which comprises: a housing defining openings therethrough for the insertion of said blades; a first contact for receiving a first of said blades; a second contact for receiving a second of said blades, said second contact including a plurality of electrically conductive segments electrically insulated from one another and disposed to be sequentially contacted by said second blade upon its insertion therein; means for connecting said first contact and the first, innermost, segment of said second contact to a power source; a semiconductor control element connected between the first and a second of said segments, said control element normally being substantially non-conductive but adapted to be rendered conductive in at least one direction by a trigger signal; and triggering circuit means energizable from a third of said segments to apply said trigger signal to said control element.

14. An electrical outlet for receiving the blades of a connector plug therein which comprises: a housing defining openings therethrough for the insertion of said blades; a first contact for receiving a first of said blades; a second contact for receiving a second of said blades, said second contact including outer, central, and inner electrically conductive segments electrically insulated from one another and disposed to be sequentially contacted by said second blade upon its insertion therein; means for connecting said first contact and said inner segment to a power source; a semiconductor control element connected between the inner and outer segments, said control element normally being substantially non-conductive to maintain said outer segment in a deenergized condition but adapted to be rendered conductive in at least one direction by a trigger signal; and triggering circuit means energizable from said central segment to apply said trigger signal to said control element.

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