May 12, 1970 HAJIME GOTO 3,512,111

SPEEDY OPERATIVE CIRCUIT PROTECTOR

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FIG. 1

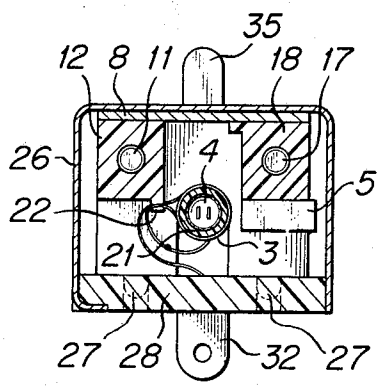


FIG. 2

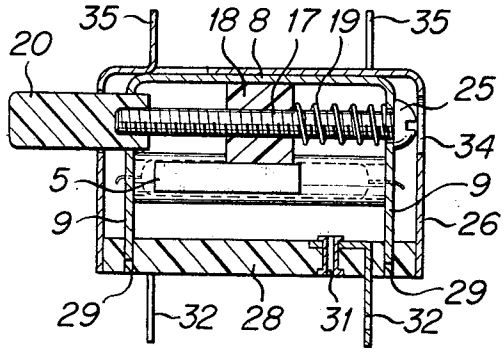


FIG. 3

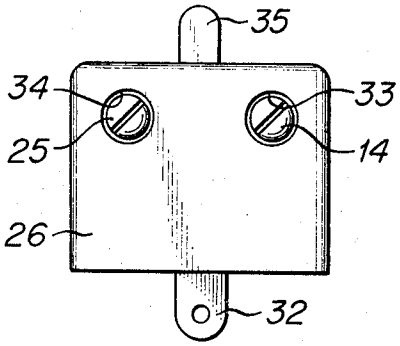


FIG. 4

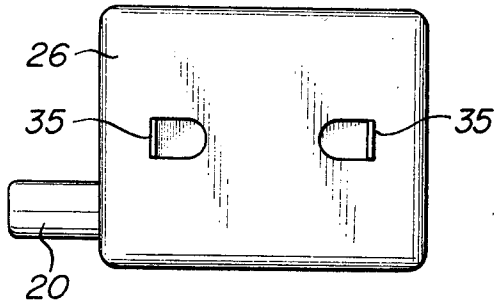


FIG. 5

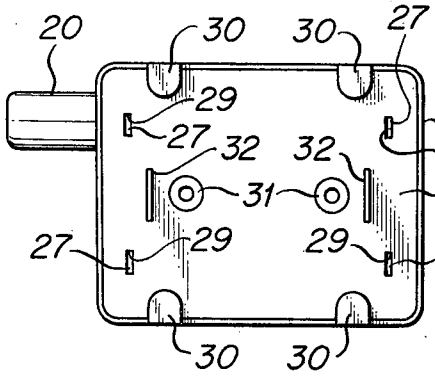
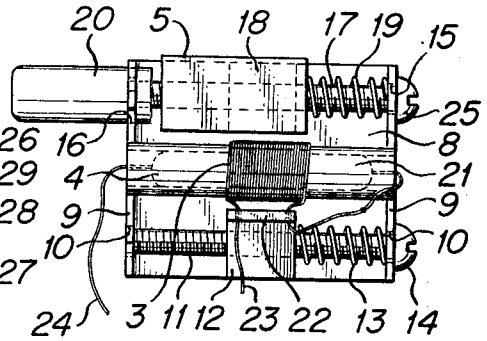


FIG. 6



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SPEEDY OPERATIVE CIRCUIT PROTECTOR

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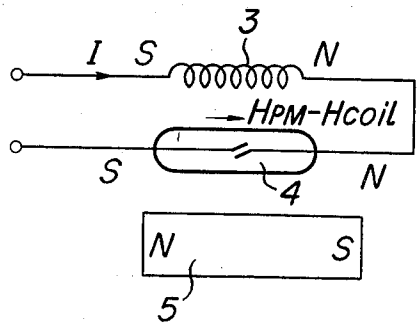


FIG. 7

FIG. 8

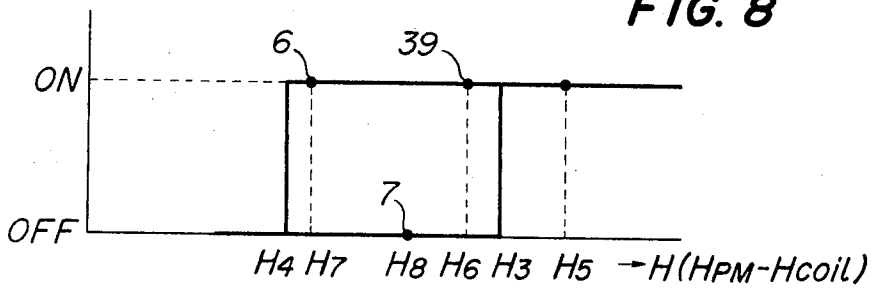


FIG. 9

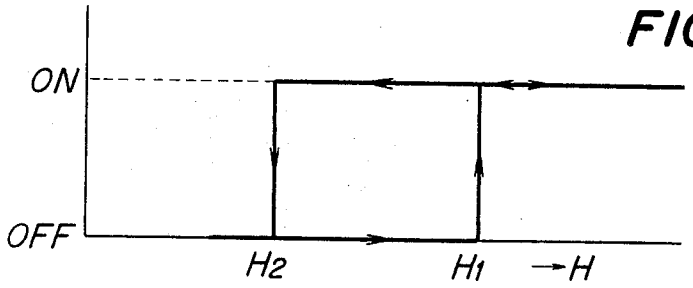
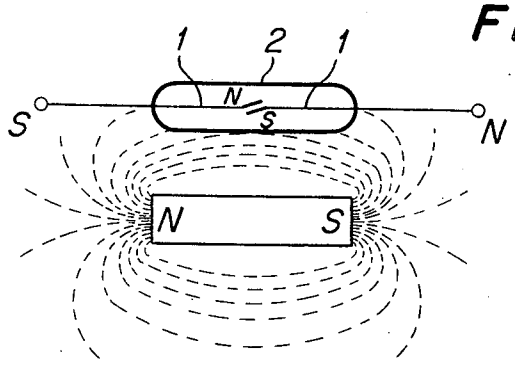


FIG. 10



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SPEEDY OPERATIVE CIRCUIT PROTECTOR

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FIG. 11

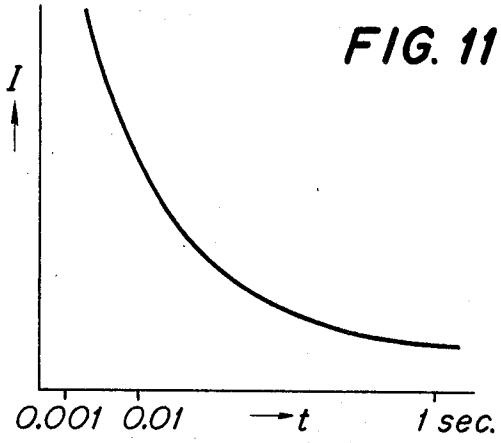


FIG. 12

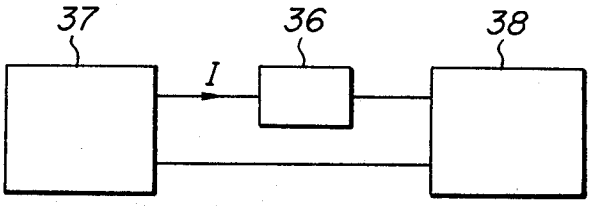
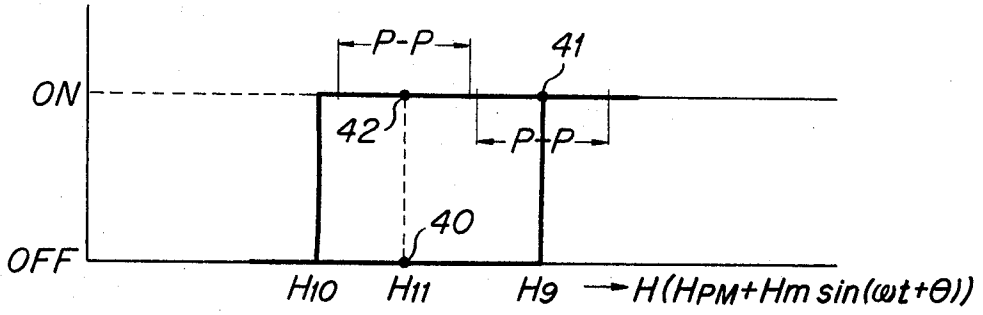


FIG. 13



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Patented May 12, 1970

3,512,111

SPEEDY OPERATIVE CIRCUIT PROTECTOR

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Filed June 3, 1968, Ser. No. 733,889
Claims priority, application Japan, Dec. 29, 1967, 84,511
Int. Cl. H01h 1/66, 51/22
U.S. Cl. 335—153
3 Claims

ABSTRACT OF THE DISCLOSURE

A circuit protector device wherein a two contact switch of magnetic material is disposed in a container which is surrounded by a coil in series with the switch. A permanent magnet is disposed in the vicinity of the switch, and, when moved towards the switch acts to close the contact. This permits a current to flow through the switch and through the coil. The direction of current flow and the coil winding is such as to produce a magnetic field counter to that of the permanent magnet. Nevertheless, when the magnet is withdrawn away from the contacts a certain distance, the contacts remain closed, the field strength of the magnet about balancing the counter field strength of the coil and switch. When an abnormally large current flows across the coil, this opens up the switch.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to a switch useful as a rapid circuit protector and more particularly to a rapid circuit protector useful against an excess current in an electric circuit.

Since semiconductor circuits or integrated circuits generally use weak currents, these circuits are defective from the standpoint of an over current flow especially in cases where a valve circuit i.e., vacuum tube arrangement has been employed in the past. Because of this over-current flow defect, there are many cases where semi-conductor circuits or integrated circuits cannot be employed owing to the fact that they cannot be provided with a proper, reliable rapid operative circuit protector.

Description of the prior art

Heretofore, as a protection against an over current in a semiconductor circuit, to protect the circuit from an abnormal over current, it has been customary to interpose another semiconductor unit between the first semiconductor circuit which was to be protected interposed and the electric source, the semiconductor unit can be broken in a very short time to disconnect the electric source when subjected to an over current. However, it has proven to be considerable trouble to change the protective semiconductor unit ever time it blows.

The arrangement of the protective unit of the present invention will eliminate such difficulty.

Summary of the invention

Broadly stated, the present invention contemplates using a magnet to close a two contact switch allowing an electric current to flow therethrough. With the flow of current, a weak magnetic field is created around the switch also by the current flow. Even though counter to the magnet's field, the withdrawal of the magnet still will not open the switch. In series with the switch is a coil which also acquires a magnetic field with current flow therethrough. This coil magnetic field also acts on the switch but is insufficient to upset the combination of the magnetic field caused by the flowing current as well as the magnetic field of the withdrawn magnet. However, a large surge of current through the coil will increase the magnetic field in the coil and open up the switch.

The objects and advantages of the invention will become more readily apparent to persons skilled in the art from the following detailed specification and annexed drawings.

Brief description of the drawings

FIG. 1 is an elevated cross-sectional view of the device contemplated herein;

FIG. 2 is an elevated cross-sectional side view of the device shown in FIG. 1;

FIG. 3 is a back view of the device contemplated herein;

FIG. 4 is a plane view of the device contemplated herein;

FIG. 5 is a view of the device shown in FIG. 1 from the under side thereof;

FIG. 6 is a cross-sectional view of the bottom of the drum contemplated herein;

FIG. 7 is a connection schematic and block diagram of the electric circuit of the device contemplated herein;

FIG. 8 is an illustration of an operating circuit;

FIG. 9 is a graphic illustration of the operation of the device contemplated herein;

FIG. 10 is simplified explanation of the operation of a switch arrangement contemplated herein;

FIG. 11 illustrates in graphic form a curve of the breaking point in a semiconductor circuit;

FIG. 12 is a block circuit diagram of the use of the protective device herein contemplated in a circuit; and,

FIG. 13 is a graphic explanation of an operating circuit employing the device herein contemplated while using A-C current.

Detailed description

Generally speaking the present invention contemplates a circuit protector device wherein a two contact switch of magnetic material is disposed in a container which is surrounded by a coil which is in series with the switch. A permanent magnet is disposed in the vicinity of the switch, and, when moved towards the switch acts to close the contacts. With the closing of the contacts, a current flows through the switch and through the coil. The coil is so wound as to produce a magnetic field counter to that of the permanent magnet. However, the flow of current through the contacts also causes a magnetic field to flow which is counter to the magnetic field of the permanent magnet. Nevertheless, when the magnet is withdrawn away from the contacts a certain distance, the contacts remain closed, the field strength of the magnet about balancing the counter field strength of the coil and switch. Means are provided for adjusting the positions of the magnet and coil to set the field strength at desired levels so as to open the switch contacts at predetermined overload conditions.

A two contact switch is employed as the key switch component. The switch consists of a glass tube or envelope **2** in which is disposed a switch unit formed of two contact pieces **1** of permalloy, a magnetic alloy of nickel and iron having a high permeability and, an inert gas. The switch tube **2** is sealed and, the switch contacts at the end of the permalloy switch unit **4** are closed by means of the attractive force of a magnet or the energizing of a coil wound on the outer surface of the switch tube.

Considering a prior art type reed relay first, only the coil and the switch when the coil, wound on outer surface of the switch tube is energized, and the energizing electric current is increased from zero upwards, the intensity of the magnetic field around the coil is increased and

rises up to a value H_1, as shown in FIG. 9. The contact of the switch is closed, and is kept closed by the electric current further increasing so as to make H more intense. If on the other hand there is a decrease in the electric current until the intensity of the magnetic field comes down to H_1, the contact do not open but are opened at less intense magnetic field value of H_2. This value H_2 is less than the magnetic field value which existed when the contact was closed. Accordingly, between magnetic field values H_2 and H_1, there exists a kind of stable area wherein the contact remains in the closed state. The circuit protector arrangement herein contemplated makes advantage use of this situation.

The basic circuit configuration contemplated is shown in FIG. 7. Here, a coil **3** is connected, in series with a switch **4** in a circuit. The two terminals shown, are to be disregarded for the moment for a clearer understanding of the invention. There is provided a permanent magnet **5** next to switch **4**.

When the switch circuit protector is interposed between an electric circuit to be protected and a source of D-C current, the switch is acted upon differently, first by the magnetizing force caused by D-C current flow I flowing in the coil **3** and second, by the permanent magnet **5**. Both of these magnetic fields have an influence on the stable area hereinbefore mentioned with respect to the understood stability of the switch **4**. This may be better understood by a study of FIG. 8. To enable the circuit protector i.e., by having it act on the electric circuit, it is necessary to first close the contact. To do this it is necessary to create a magnetic force H, which will influence the switch, of a value exceeding or equal to H_3. The permanent magnet **5** should be brought close enough to the switch **4** to accomplish this. When the switch contacts are closed the current flow is in a direction to counter the intensity of magnetic field caused by the permanent magnet **5**. This will lower the field value to H_6. This is sufficient to keep the contacts closed owing to the proximity of permanent magnet **5** to the switch **4**.

Thus, it is impossible to open the contacts or to keep them open even though there is a current larger than H_4 the switch will open. However, in this case, the operative point is too deep and it takes too long to open the switch.

To properly fix the operative point of the circuit protector, the permanent magnet **5** has to be placed a little further away from switch **4** to decrease the magnetic force acting thereon, so as to draw this magnetic force nearer to H_4, i.e., to about the operative point **6** corresponding to magnetic force H_7. Under these conditions, when an electric current of from about 1.5 to about 1.8 times the rated current flows, the instantaneous magnetic force becomes less than H_4, and the contacts are opened. Then, the magnetic force produced by coil **3** goes to zero, and the operative point moves to point **7** changing the magnetic force to H_8, which in this case, should be smaller than H_3. By making use of this arrangement the switch whose operation has just been described is used as a circuit protector.

In a circuit overload breakdown test, as illustrated in FIG. 11, the horizontal coordinate shows the time during which an abnormal over current is flowing, and the vertical coordinate shows the value of said current. The curve so obtained illustrates that the shorter the flowing time of an over current, the stronger is the circuit resistance against breakdown against the over current.

In carrying out the foregoing concepts into practice, the construction shown in FIGS. 1 to 6 is advantageous. In these figures there is shown a circuit protector arrangement having a switch **4** for controlling a main electric current. A permanent magnet **5** is disposed, adjacent to the switch **4**. The switch is contained in a sealed tube surrounded by a coil **3** so disposed with respect to the permanent magnet **5** as to define as near as possible the lower field value of the stabilized field hereinabove described with respect to switch **4**. In order to close the contact **1** of the switch **4** there is provided a hand button which will place the permanent magnet **5** close to the contact which are to be set or reset. Coil **3** is connected in series to the switch **4** over which is created the magnetic field caused by the coil. In the example shown the arangement is set for a D-C current. Coil **3** which is connected in series to said lead switch **4**. The value of the magnetic field around the coil is normally less than that of the permanent magnet **5**.

The device is housed in a frame **8** having a U-shape. In the side plates **9** of U-shaped frame **8** there is an aperture **10** for inserting a first screw rod **11**. Screw rod **11** has a first insulating block **12** mounted thereon. Between the insulating block **12** and one side of one plate **9** there is provided a spring **13**. The spring is mounted towards the head of screw rod **11**. The head **14** of the screw rod is disposed outside of the plate **9** and can be turned by a screw drive so that the first insulating block **12** can be moved up and back within frame **8**.

On the opposite sides of plate **9** are other apertures **15** and **16** for inserting a second screw rod into the one **15** and the other **16** aperture and for a push button **20**, mounted on the outer end of rod **17**. Mounted on second rod **17** is a second insulating block **18**. Also on screw rod **17** on the side of aperture **15** between second insulation block **18** and side plate **9** is a spring **19**. Thus, on one end of second rod **17** is spring **19** while on the other end is a push button **20**.

Insulating block **18** can be moved against the reaction of spring **19** by pushing the button **20** by hand and returns to its former position by releasing the button.

Mounted in the center of U-shaped frame **8** is an elongated hollow insulated tube **21** which is fixed to the center of frame **8**, i.e., to opposed plates **9** of the frame **8**. Permalloy switch **4** is disposed in tube **21**, and, around tube **21** and over the contact points of switch **4** is wound an insulated wire coil **3**. Coil **3** is electrically in series with switch **4**. Thus the lead lines of the switch **4** pass through apertures at both ends of tube **21** and the inner lead of the switch acts as the inner lead of the coil. This inner lead of switch and coil is held on the upper portion of first insulating block **12**. In other words, one end of coil **3** is connected to the lead wire of switch **4**. The other lead wire end **23** of coil **3**, together with the other lead wire **24** of the switch **4**, are connected to the power line terminals of the device. The other lead wire end **23** of the coil passes through first insulating block **12**. Both leads **23** and **24** then pass out of an eyelet **31** (see FIG. 2) of the device.

Affixed to second insulating block **18** is a permanent magnet **5**, which is disposed so as to provide a magnetic field over switch **4**. By turning the head **25** of screw rod **17** with a screwdriver, permanent magnet **5** can be moved slightly for controlling the location of the magnetic force field H_7. By pushing button **20** by a hand, magnet **5** is moved nearer to the contact points of the switch **4** for increasing the magnetic field so as to close the contacts. In this way, the circuit protector device can be set or reset.

The main components of the circuit protector device constructed as hereinbefore described is contained in a housing **26**. Button **20** projects out of the housing. The housing forms a single unit with the frame **8** and frame insulating plate **28** by the use of dowel-like projections **27** located on the outer sides of plates **9** of the base frame **8**. These dowel-like projections fit into holes **29** of the insulating plate **28**. The projections **30** formed on the housing **26** are bent so as to secure insulation plate **28** to complete the package.

Insulating plate **28** is also held by means of eyelets **31** serving the double purpose of acting as holding means and as passages for circuit lead **23** of the coil **3** and for the lead **24** of the switch **4**. These leads are pulled out through holes of the eyelet **3**.

The housing **26** is provided with two apertures **33**, **34**, one of which **33** is for controlling the relationship between switch **4** and the coil **3** by moving the latter together with the insulating plate **12** which holds the both ends of the coil **3**. Screw rod **11** is turned by using a screwdriver inserted at aperture **33**. The other aperture **34** is for controlling the magnetic field H_7 of the circuit protector by turning screw rod **17** with a screwdriver which is inserted at hole **34**.

Since button **20** is pushed in and out for set or reset, and screw rod **11** extends out from base frame **8**, the diameter of aperture **33** should be large enough to pass the top head **25** of screw rod **17** through it. The numeral **35** in FIG. 4 indicates a fixed portion of the circuit protector located in housing **26**. The device operates as follows:

As shown in FIG. 12, the circuit protector device **36** is connected between an electric source **37** of a D–C current and the semiconductor circuit **38** to be protected. The circuit is designed for a rated current I. Button **20** is pushed so that the permanent magnet **5** approaches the contacts of the switch **4** increasing the magnetic field around the switch to close the contacts of the switch **4** so that current I is fed to the semiconductor circuit to be protected. The magnetic field force acting on the contacts at this time, will be increased from H_8 to H_5 (see FIG. 8).

After the contacts have been closed, a magnetic field is formed by the action of current I flowing in the circuit. This field is opposite to the field caused by the permanent magnet **5** and decreases the magnetic field acting upon the contacts, but the magnetic field of the permanent magnet **5** is still sufficiently large to keep the contacts closed. This magnetic field is labeled as H_6 which corresponds to point **39** in FIG. 8.

Upon releasing button **20** the permanent magnet **5** returns to its former position by the action of spring **19**, and the magnetic field acting on the contacts labeled H_7 corresponding to point **6**. The device is now prepared against an abnormally large electric current, and the circuit protector device is all set to work.

Point **6** corresponding to magnetic field H_7, is controlled by turning screw rod **17**. This point depends on the construction of the device taking into consideration, the magnetizing force of the permanent magnet **5** and the ampere turn of coil **3**.

It is possible to control this magnetizing force minutely for the purpose of defining the breaking point of the electric circuit.

By properly turning screw rod **17**, an operative point can be selected for the highest speed and it is also possible to correct the contacting pressure of the contacts which causes distortion in the flexibility of the contacts **1** of the switch **4** or, by distortion of magnetic reluctance of the unit. Thus it is possible to manufacture circuit protector devices having distortion peculiarities and these can then be corrected by adjustment.

As described above, when a magnetic field H_7 acts on the contacts of the switch **4**, if a current of from about 1.5 to about 1.8 times the rated current is sent through the circuit protector, the magnetic field of the coil **3** will be increased. Since the magnetic field H equals the permanent magnetic field less the coil field, or $H=(H_{pm}-H$ coil). When the field decreases below point H_4, the contacts of switch **4** will open and the operative point of the switch will be moved to point **7**. Thus, an over current in the electric circuit of the semiconductor to be protected is cut in an instant.

When it is necessary to reset the electric circuit, by pushing the button **20**, it can be done like the setting of the circuit.

Although the arrangement hereinbefore described relates to a circuit protector for a D-C current system, the system can also be used for an A-C current.

In case the electric source has a sinusoidal output of 50 or 60 Hertz, the magnetic field produced by the coil **3** is also an alternating field, of 50 or 60 cycles per second.

Considering these conditions, each operative point can be set, as illustrated in FIG. 13. Assuring that when the magnetic field acting on switch **4** reaches a value of to H_9, the contacts are closed, but when the magnetic field reaches a value of H_{10}, the contacts are opened at the same time, assuming that, when the permanent magnet **5** is in position in accordance with the reaction of the spring **19**, the operative point would be on a point **40** corresponding to magnetic field H_{11}, acting on the switch **4**, the point **40** will be moved to the right, by letting the permanent magnet **5** draw nearer to the contacts. By pushing button **20** the operative point is moved to location **41**, and the magnetic field value becomes H_9.

Then the magnetic field of the coil **3** can be expressed as $Hm \sin(wt+0)$. To this is added the force of the permanent magnet, the magnetic field acting on the contacts of the switch **4**.

The magnetic field can be mathematically described as $Hpm+Hm \sin(wt+\theta)$, (assuming $w=\alpha\pi f$, where f is the frequency of the source); θ=initial phase; Hm=maximum value of the magnetic field of the coil, and Hpm the value of the magnetic field of the permanent magnet.

The contacts will be closed by pushing button **20**. Then upon releasing the button **20**, the button returns to its former position by the action of the spring **19** so that the magnetic field oscillates around point **42** until the minimum peak wave value between plus peak and minus peak of the magnetic field produced by the coil **3**, becomes less than H_{10} so that the contacts are opened, namely, when Hm is opposed by the field strength of a high wave of current flowing in the coil **3**. When an abnormally large current flows, the value of the magnetic field of coil **3** will increase so that the contacts of the switch **4** are opened at once, making the instantaneous value $(Hpm-Hm)$ of the magnetic field $Hpm+Hm \sin(wt+\theta)$ which acts upon the switch **4**, less than the field value H_{10}. The necessary switching time of the lead switch is less than one millisecond, so that if the frequency of the electric source is of 50 Hertz a half cycle corresponds 10 milliseconds which is enough to open the contacts.

Thus the device is useful when an A-C current is the electric source. Similarly the device is adjusted by turning screw rod **17** to control the magnetic field. Acting on the contacts of the switch **4** and by using the permanent magnet **5** properly to shorten the operating time.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

I claim:

1. A circuit protector device comprising in combination:

(a) a frame (**8**);
(b) a tube (**21**) held in said frame;
(c) a two contact switch (**4**) inside said tube (**21**) said switch (**4**) being made of magnetic material;
(d) a coil (**3**) wound around said tube, in series with said switch;
(e) a rod (**17**) disposed adjacent said tube, held by said frame;
(f) a permanent magnet (**5**) mounted on said rod disposed in the vicinity of said envelope;
(g) means (**20**) for moving said permanent magnet towards and away from said switch;
(h) said means comprising a push button (**20**) on the end of said rod (**17**); and,
(i) a spring (**19**) coiled around said rod to restore said magnet to its original position, whereby, when said permanent magnet is moved towards the switch,

said switch contacts close permitting a current flow through the switch and coil, the winding of the coil being such as to produce a magnetic field counter to that of the permanent magnet, the flow of current through the contacts also causing a magnetic field around the switch so that the movement of said permanent magnet away from said switch to its original position will not cause the switch to open since the field strength of the magnet about balances the counter field strength of the coil, but an overcurrent flowing through the coil opens up the switch contacts.

2. A device as claimed in claim 1 including a second rod (11) mounted between said frame disposed adjacent said tube (21), an insulation block (12) mounted thereon, the end wires of said coil (3) passing therethrough

so as to be able to move said coil along said tube (21) for adjusting the magnetic field of the coil.

3. A device as claimed in claim 2 wherein said first and second rods are screw rods including a screw head and can be turned by turning said heads so as to laterally move said magnet (5) and said insulation block (12) with respect to said switch (4).

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R. N. ENVALL, JR., Assistant Examiner