March 12, 1968 YASUO KASAHARA 3,373,383

AUTOMATIC CURRENT LIMITING CIRCUIT BREAKER

Filed Jan. 27, 1966 4 Sheets-Sheet 1

Fig. 1

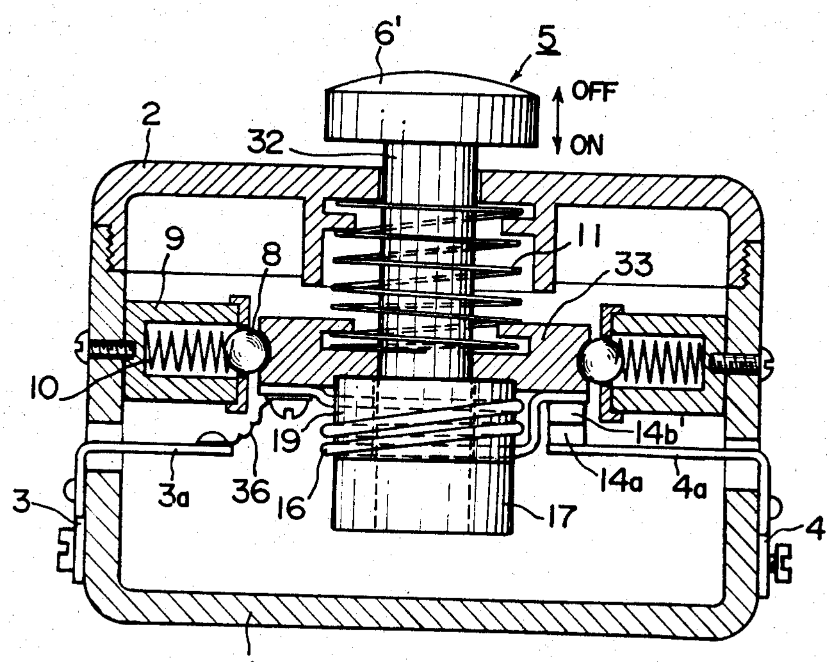

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Fig. 2

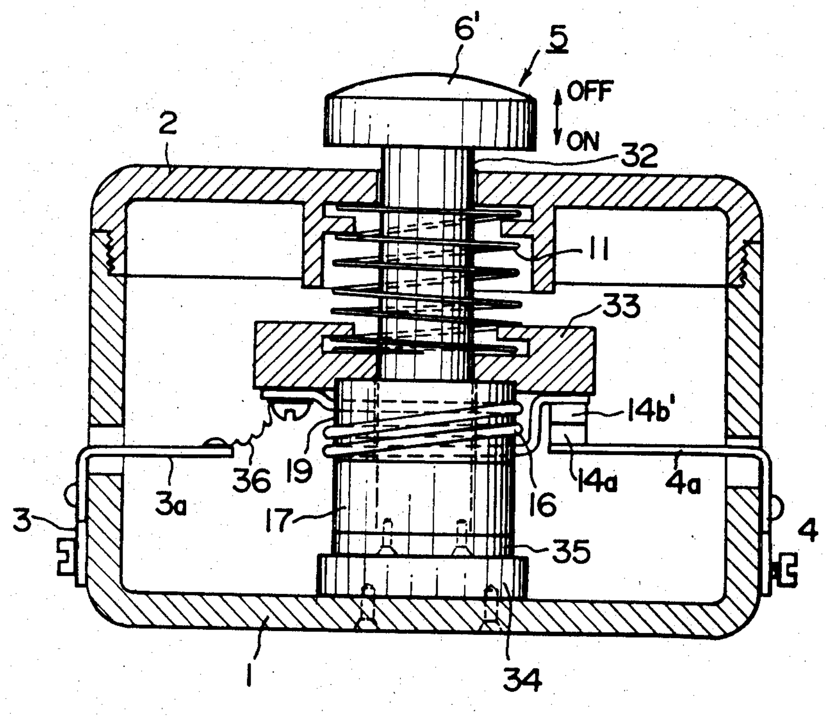

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Fig. 3

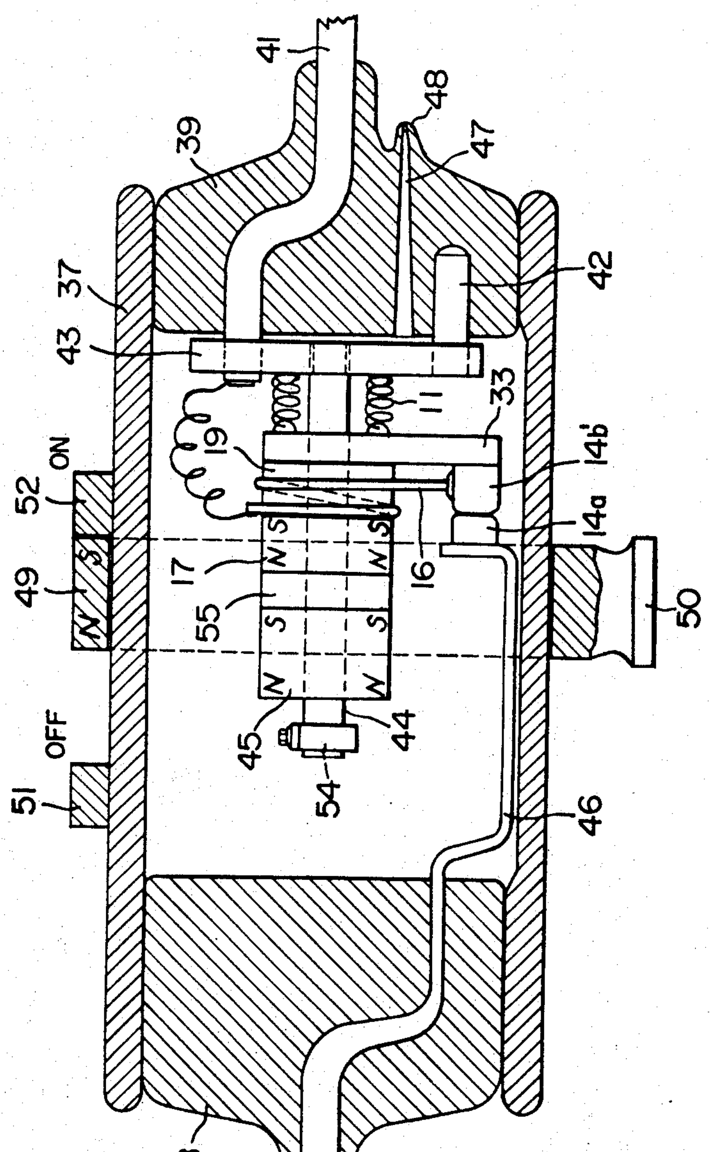

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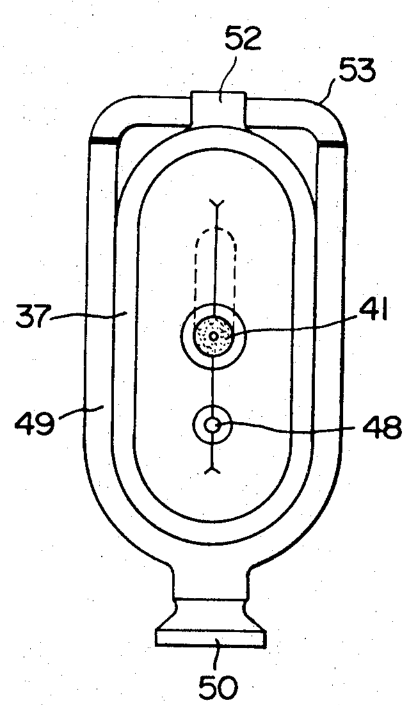
Fig. 4



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AUTOMATIC CURRENT LIMITING CIRCUIT BREAKER

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7 Claims. (Cl. 335—18)

ABSTRACT OF THE DISCLOSURE

A circuit breaker comprising a pair of contacts, an armature having thermally reversible magnetic properties and carrying one of said contacts, a magnetic locking means to attract said armature, a spring biasing the contacts away from their closed position, and a manual actuating means, whereby upon occurrence of an overcurrent, the magnetic attraction between said armature and said locking means is reduced to open said contacts.

This invention relates to a magnetic circuit breaker, more particularly an automatic current limiting circuit breaker having magnetic locking means to lock load current carrying contacts of the breaker at their closed positions under normal conditions by a magnetic force and to diminish said magnetic force responsive to an overcurrent through said contacts in excess of a certain predetermined level, so that the breaker interrupts automatically any overcurrent exceeding said predetermined level, such as an over-load current and a short-circuit current, by tripping said magnetic locking means to open said contacts.

The principal object of the invention is to provide an economical circuit breaker of simple construction having accurate and quick operating characteristics.

An object of the present invention is to provide an overcurrent responsive magnetic locking means consisting of a permanent magnet, which is characterized in that its tripping action is very accurate to ensure reliable interruption of over-load currents or short-circuit currents, and that the intensity of magnetization of said permanent magnet of the locking means is kept unchanged by such overcurrent to ensure its long life.

Another object of the invention is to provide a novel trip free mechanism to facilitate safe and reliable operation of the aforementioned overcurrent responsive locking means.

Still another object of the invention is to prevent effectively burning of current carrying contacts by sealing such contacts in a novel vacuum circuit breaker of simple construction.

For a better understanding of the invention, reference is made to the accompanying drawings, in which:

FIG. 1 is a sectional view illustrating one embodiment of the invention;

FIG. 2 is a sectional view similar to FIG. 1 illustrating an embodiment of the invention having a magnetic trip free mechanism;

FIG. 3 is a sectional view of a vacuum circuit breaker embodying the present invention; and

FIG. 4 is a side view of the vacuum circuit breaker.

Referring to FIGS. 1 and 2, reference numeral **1** designates a base plate, **2** a lid, **3** and **4** terminals, and **5** an actuating mechanism slidably mounted on the top wall of the lid.

In the embodiment of the invention as shown in FIG. 1, the actuating mechanism **5** comprises a vertically movable

knob **6'** having stem portion **32** inserted into the inside space of the breaker through the lid **2**. A slidable disk **33** fitted to the stem **32** is slidably held by a click motion mechanism comprising springs **9** and balls **8**. The slidable disk **33** carries a control conductor **16** secured thereto, and one end of said control conductor is connected to the terminal **3** of the circuit breaker through a flexible lead wire **36** while the opposite end of said conductor **16** is connected to the movable contact **14*b*'** of the switching means of the circuit breaker. Said movable contact **14*b*'** is also secured to said slidable disk **33** in such a manner that it may be brought into direct contact with the fixed contact **14*a*** of the switching means when the knob is depressed to its lowered position, while spaced from said fixed contact **14*a*** as long as said knob **6'** is pulled up and held at its raised position.

It is preferable in the embodiment of FIG. 1 to provide at least one turn in the control conductor **16**. A coiled spring **11** is inserted between the lid **2** and the slidable disk **33** by securing the upper and lower ends of the spring to said lid and slidable disk respectively, so that an elastic force may act on the slidable disk **33** in a direction to pull the disk **33** upwards.

An armature **19** made of ferromagnetic or paramagnetic substance is secured to the slidable disk **33** at the lower end thereof in a suitable manner so as to be fitted into the space between the stem **32** and the operating conductor **16**. Besides, a permanent magnet **17** is secured tightly to the lower end portion of the stem **32** in order to hold said armature **19** attracted to the permanent magnet **17** and thereby to pull down the slidable disk **33** against said elastic force of the coiled spring **11**.

Accordingly, under normal conditions, the contacts **14*a*** and **14*b*'** of the switching means are closed and opened as the knob **6'** is pushed down and pulled up vertically.

Thus, the current path tracing from the terminal **3**, through a lead conductor **3*a***, the flexible conductor **36**, the control conductor **16**, the movable contact **14*b***, the fixed contact **14*a***, and a lead wire **4*a***, to the terminal **4** is closed and opened by operating the knob **6'** of the operating mechanism **5**.

In the circuit breaker of the aforementioned construction, if an overcurrent exceeding a certain predetermined maximum allowable load current should flow through the control conductor portion **16** due to over-load, the rate of heat generation therein is increased beyond the rate of heat dissipation therefrom, and the temperature of the control conductor portion and accordingly that of the armature **19** and the permanent magnet **17** are gradually increased. Thereby, the magnetic flux density in the armature **19** is also reduced due to either thermal reversible reduction in the spontaneous magnetization of the ferromagnetic substance constituting said permanent magnet **17** or thermal reversible reduction in the permeability of the ferromagnetic or paramagnetic substance constituting said armature **19**. As said magnetic flux density in the locking means is reduced, the magnitude of the elastic bias force of the coiled spring **11** becomes greater than that of the magnetic locking force acting between the permanent magnet **17** and the armature **19**, and hence the armature **19** is pulled upwards together with the plate **33** along the stem **32**. Thus the movable contact **14*b*'** is separated from the stationary contact **14*a*** to interrupt the overcurrent. Since the speed of said reduction in the magnetic flux density in the armature **19** and accordingly the reduction in the locking force acting on the movable contact **14*b*'** depends on the magnitude of the current flowing through the control conductor **16**, a suitable time delay can be provided to said interruption of the overcurrent by proper design of heat dissipation therefrom.

On the other hand, if the current through the control conductor **16** is increased suddenly to an extremely high magnitude, for instance a short-circuit current due to a serious fault in the circuit connected thereto, the reluctance of the magnetic circuit through the armature 19 is increased instantaneously to diminish the attraction between said armature 19 and the permanent magnet 17. Thus, the circuit through the contacts 14*a*, 14*b'* is opened at a high speed to interrupt the large overcurrent. The inventor found that the aforesaid increase of reluctance of the armature due to an extremely large current is not affected by the direction of the current, and that the interruption of such extremely large current can be made within one cycle of commercial power frequency, e.g. 50 cycles or 60 cycles per second.

In order to carry out the above interruption of the overcurrent successfully, the elastic force to pull up the slidable disk 33 should be at least greater than the magnitude of force of the click action mechanism to hold the disk 33, however, said elastic force should be smaller than the composite effect of the magnetic force to pull down the disk 33 under normal conditions and said force of the click action mechanism to hold the disk 33.

The construction of the click action mechanism is not limited to those shown in FIG. 1, but any other suitable construction, such as a magnetic device as shown in FIG. 2, can be also used satisfactorily together with the circuit breaker of the present invention. In the click action mechanism of FIG. 2, the operating knob 6' is locked at its lowered position by means of a magnetic attraction between a fixed magnetic element 34 secured to the base plate 1 and a movable magnetic element 35 secured to the lower end portion of the stem 32 of the operating mechanism 5. Once the knob 6' is raised upwards by a sufficiently large force while overcoming said magnetic attraction between said magnetic elements, the knob 6' is pulled upwards all the way through to its completely raised position by means of the elastic force of the spring 11.

FIGS. 3 and 4 illustrate a vacuum circuit breaker having a switching and locking mechanism similar to the one shown in FIG. 1 which has a considerably larger interrupting capacity compared with that of the breaker of FIG. 1. Referring to FIG. 3, the reference numeral 37 designates a tube made of non-magnetic material such as glass, and 38, 39 are sealing members made of similar non-magnetic materials such as glass to seal the tube 37. The sealing members 38, 39 are so fitted to both ends of the tube 37 as to seal airtightly the intermediate portion of the tube. Such fitting is obtained by placing ring-shaped glass bodies having lead wires 40 and 41 therethrough at proper positions and then by shaping them into the desired form by pressing after softening them at an elevated temperature.

Legs 42 for supporting a base plate 43 are embedded in the sealing member 39 during the above process of shaping at an elevated temperature. The base plate 43 is then secured to the inner ends of the lead conductor 41 and the legs 42.

A guide stem 44 is secured to the base plate 43 to guide the movement of a slidable plate 33 having a movable contact 14*b'* extending therefrom and an armature 19 secured thereto. The guide stem 44 also penetrates through a pair of permanent magnets consisting of a holding magnet 17 and an operating magnet 45 spaced from each other by a spacer 55 of non-magnetic material in such a manner that the extreme right end surface of the holding magnet 17 makes direct contact with the extreme left hand end surface of said armature 19 as viewed from the front of FIG. 3 when the contacts 14*b'* and 14*a* of the switching means are closed. At the extreme left hand side end of the guide stem 44, a stopper ring 54 is mounted to limit the movement of said magnets 17 and 45. Coiled springs 11 are inserted between the base plate 43 and the slidable plate 33 by securing each end thereof to said base plate and slidable plate respectively as shown in FIG. 3. The coiled springs 11 provide a bias force to the slidable plate 33 in a direction away from the permanent magnet 17, however, the magnitude of said elastic

biasing force is slightly smaller than that of a magnetic attraction between the armature 19 on the slidable plate 33 and the holding magnet 17 when the switching means is at its closed position.

An operating conductor 16 is wound around the armature 19 so as to provide at least one turn, and one end of the conductor 16 is connected to the lead conductor 41 while the opposite end of operating conductor is connected to the movable contact 14*b'*. The fixed contact 14*a* of the switching means is connected to the lead conductor 40 and supported suitably so as to be positioned opposite to the movable contact 14*b'*.

The intensity of magnetization of the holding magnet 17 is just high enough to hold the armature 19 and accordingly the slidable plate 33 is attracted thereto under normal conditions once the switching means is closed against the biasing force of the springs 11. The intensity of magnetization of the operating magnet 45 should be high enough to produce a sufficiently large magnetic force between the magnet 45 and the control magnet 49 to be described hereinafter. Said two magnets 17 and 45 are secured together with the spacer 55 between them so that they may slide along the guide stem 44 as an integral unit.

The aforementioned internal elements and members of the circuit breaker are placed inside of a slightly flattened tube 37 of non-magnetic substance as shown in FIG. 4, and then sealing members 39 and 38 are fitted airtightly to the tube 37 at an elevated temperature, and thereafter the air inside of the tube is pumped out through an outlet passageway 47 defined in the sealing member 39. After a proper degree of vacuum is obtained in the tube by said pumping, the outlet passageway 47 is sealed off at its outer end as shown by 48 in FIG. 3.

A tuning fork-shaped actuating magnet 49 having a knob 50 is fitted to the outside of said tube 37 so as to be slidable in a longitudinal direction of the tube.

The actuating magnet 49 is magnetized in the same polarity as that of the operating magnet 45, for instance, both the magnets 45 and 49 are magnetized so as to produce S poles at the sides closer to the slidable plate 33, as shown in FIG. 3, thereby the same side of the magnets 49 and 45 are repelled by each other by the magnetic force acting between poles of the same polarity.

If the contacts 14*a* and 14*b'* of the switching means are closed while the actuating magnet 49 is held at a position adjacent to a stopper 52 at the extreme right hand side end of the moving stroke of the control magnet, there are produced repulsive forces between magnetic poles of the same polarity of magnets 45 and 49 to exert a force to the operating magnet 45 in a direction away from the slidable plate 33, which is urged against the fixed terminal 14*a* by the magnetic attraction between the holding magnet 17 and the armature 19 secured to the slidable plate. Since the composite effect of said repulsive forces is selected to be larger than the composite effect of the biasing forces of springs 11 but smaller than the magnitude of the attraction between the magnet 17 and the armature 19, the movable contact 14*b'* of the switching means is locked at its closed position, as illustrated in FIG. 3.

If the control magent 49 is moved leftward from the position shown in FIG. 3, the geometrical distances between similar poles of magnets 49 and 45 is reduced and accordingly the magnitude of the repulsive force between them is increased, however, due to mechanical engagement between contacts 14*a* and 14*b'* and the attraction between the holding magnet 17 and the armature 19, the magnets 45 and 17 are held still at the position shown in FIG. 3. As the control magnet 49 is moved further leftward and the distance between magnetic poles of opposite polarities of magnets 49 and 45 becomes close to the distance between poles of similar polarity, the magnitude of the repulsive force between them is reduced, and as soon as the composite effect of the elastic biasing forces of the springs **11** exceeds that of the above repulsive forces between magnets **49** and **45**, the slidable plate **33** and magnets **17**, **45** are pulled toward the base plate **43** as an integral body in one stroke. Thereby, the contacts **14***a* and 14*b'* are separated from each other in a snap action.

It is apparent now that the contacts **14***a* and **14***b'* will be closed again by shifting the control magnet **49** rightward from its extreme left end position by a stopper **51** located at that end of the stroke of the actuating magnet **49** which is farthest from the base plate 43.

In FIG. 4, the reference numeral **53** represents a yoke member bridging the top portions of the tuning-fork-shaped control magnet **49**.

With the switching and locking means as shown in FIGS. 3 and 4, if the magnitude of the current passing through the operating conductor **16** is increased beyond a certain predetermined level, the attraction between the holding magnet **17** and the armature **19** is diminished and the slidable plate **33** is pulled toward the base plate **43** by means of the elastic biasing force of springs **11**, in the similar manner to that in the preceding example described referring to FIG. 1.

It is also apparent in the circuit breakers of FIGS. 3 and 4 that the actuating magnet **49** is kept at its ON position when the circuit through the contacts **14***a* and **14***b'* is interrupted automatically responsive to overcurrent, and that the actuating magnet **49** should be moved to its OFF position once in order to reclose the contacts **14***a* and **14***b'* of the switching means after the automatic interruption. Thus, the operation of the circuit breaker is made trip free.

What I claim is:

1. An automatic current-limiting circuit breaker comprising conductor means, switching means including a pair of make-and-break contacts movable to complete a circuit through said conductor means in one position thereof and to interrupt the circuit through said conductor means in another position thereof, an armature made of magnetic substance having thermally reversible magnetic properties, said armature carrying one contact of said switching means, a magnetic locking means to attract said armature to lock said switching means in said one position, spring means biasing said switching means toward said another position, and manual actuating means adapted to assume a closed position for keeping said switching means in said one position and to assume an open position for keeping said switching means in said another position, said conductor means having a coiled portion including at least one turn surrounding said armature, whereby upon occurrence of an overcurrent in said conductor means the magnetic attraction between said armature and said locking means is

reduced to such an extent that the biasing effect of said spring means becomes greater than said magnetic attraction so as to move said switching means from said one position to said another position to interrupt said circuit without causing shifting of said actuating means.

2. A circuit breaker according to claim 1, wherein said armature made of magnetic substance is a permanent magnet.

3. A circuit breaker according to claim **1**, wherein said magnetic locking means includes a permanent magnet to attract said armature made of magnetic substance.

4. A circuit breaker according to claim **1**, wherein said actuating means is a vertical rod having said magnetic locking means secured at the lower end thereof, said armature means is an annular member of magnetic substance slidably fitted around said rod, and said spring means is inserted between a casing of the breaker and said armature.

5. A circuit breaker according to claim **1** and further comprising a guide stem and a pair of permanent magnets, wherein said magnetic locking means has an annular holding magnet to attract said armature and said holding magnet is carried by said guide stem in a slidable manner, and said pair of permanent magnets includes an operating magnet having a substantially higher intensity of magnetization than that of said holding magnet and joined to said holding magnet with a non-magnetic spacer inserted therebetween, and an actuating magnet constituting said manual actuating means and spaced from said operating magnet, said actuating magnet having an intensity of magnetizatin high enough to actuate said operating magnet at a position spaced therefrom so that said switching means may be moved between said one position and said another position by moving said actuating magnet.

6. A circuit breaker according to claim **5**, wherein said operating magnet acts also as a part of said magnetic locking means to dispense with said holding magnet.

7. A circuit breaker according to claim **5**, wherein said breaker is placed in an evacuated housing except said manual actuator made of said actuating magnet.

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