United States Patent

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[15] **3,663,906**

[45] **May 16, 1972**

[54] ELECTRIC CIRCUIT BREAKER WITH MAGNETICALLY ASSISTED CLOSING MEANS

[72] Inventors: **Philip Barkan; Klaus M. Skreiner,** both of Media, Pa.

[73] Assignee: **General Electric Company**

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[52] **U.S. Cl.** **335/195**

[51] **Int. Cl.** **H01h 3/42**

[58] **Field of Search** 335/195, 16, 147

[56] **References Cited**

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Primary Examiner—Harold Broome

Attorney—J. Wesley Haubner, William Freedman, Frank L. Neuhauser, Oscar B. Waddell and Joseph B. Forman

[57] **ABSTRACT**

An electric circuit breaker containing electromagnetic-assist means for opposing the contact-repulsion forces developed when a high current flows through the breaker. The electromagnetic-assist means comprises a rigid support member which when restrained in a fixed position renders the assist means capable of transmitting closing force to the movable contact but which, when released, disable the assist means. Releasable latching means restrains the support member in said fixed position when the contacts are engaged. This latching means is controlled by the motion of a contact-operating member that is coupled to the movable contact through a suitable wipe mechanism.

16 Claims, 5 Drawing Figures

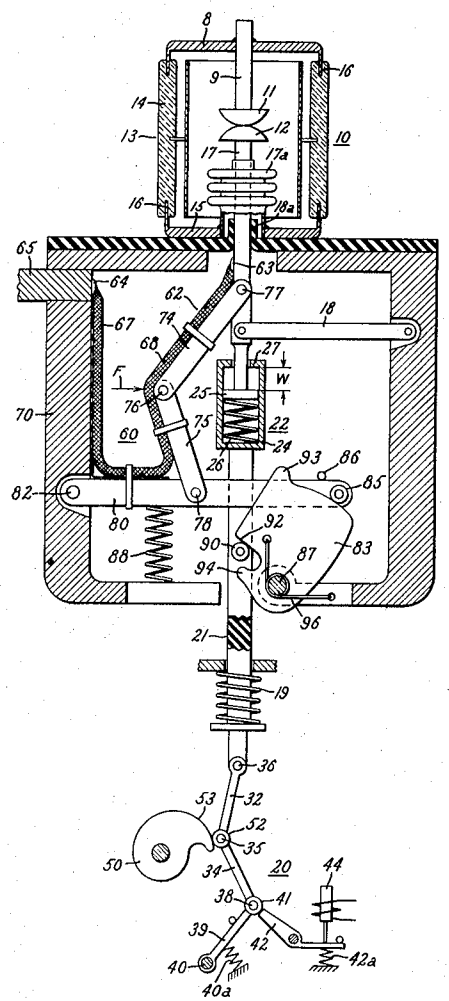

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Fig. 1.

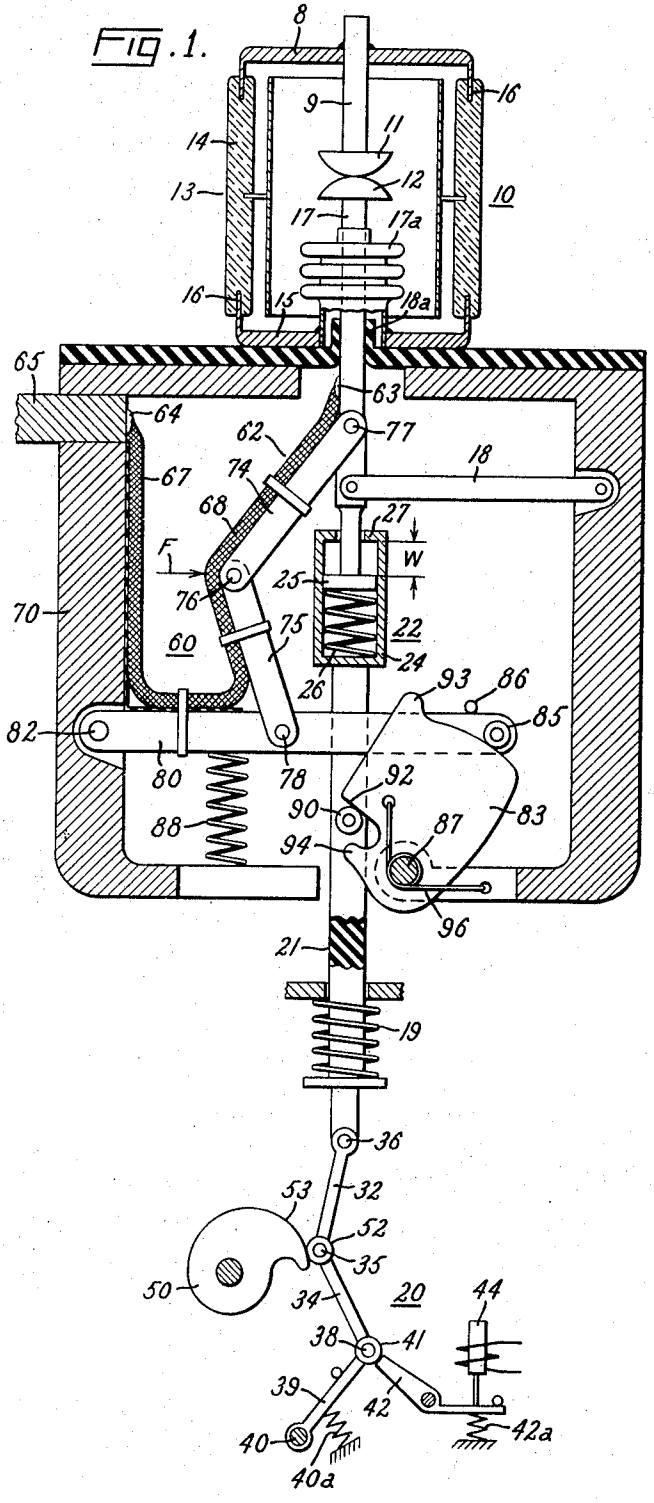
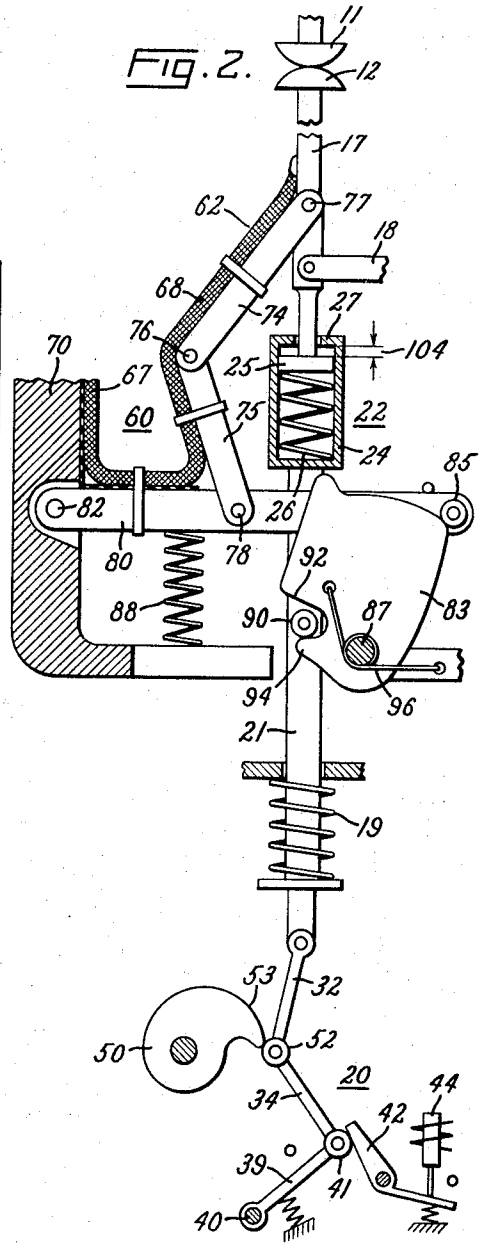


Fig. 2.



INVENTORS:
PHILIP BARKAN,
KLAUS M. SKREINER,
BY William Freedman
ATTORNEY

Fig. 3.

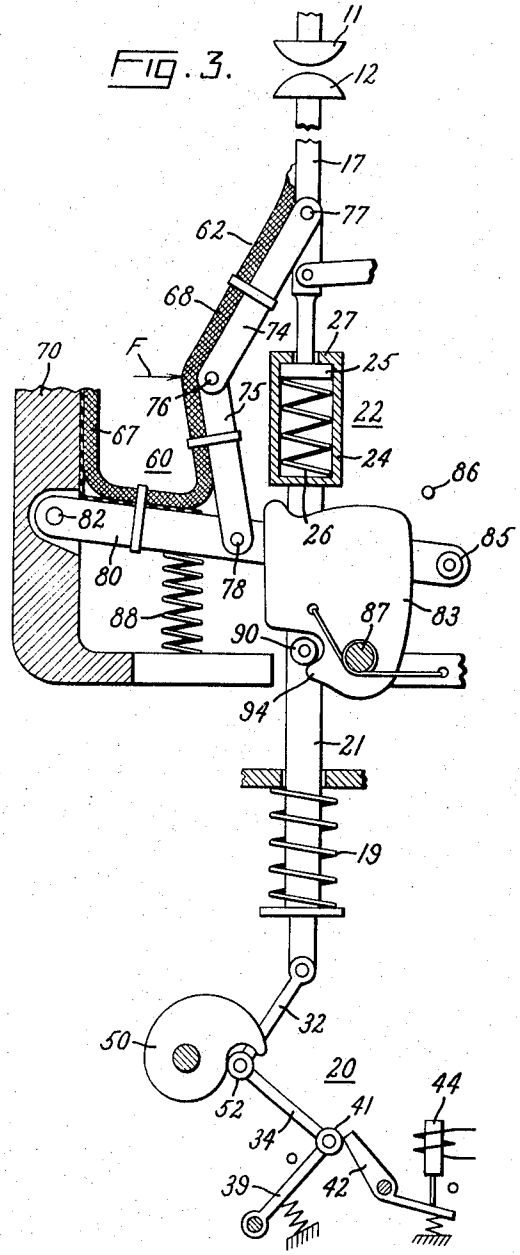


Fig. 4.

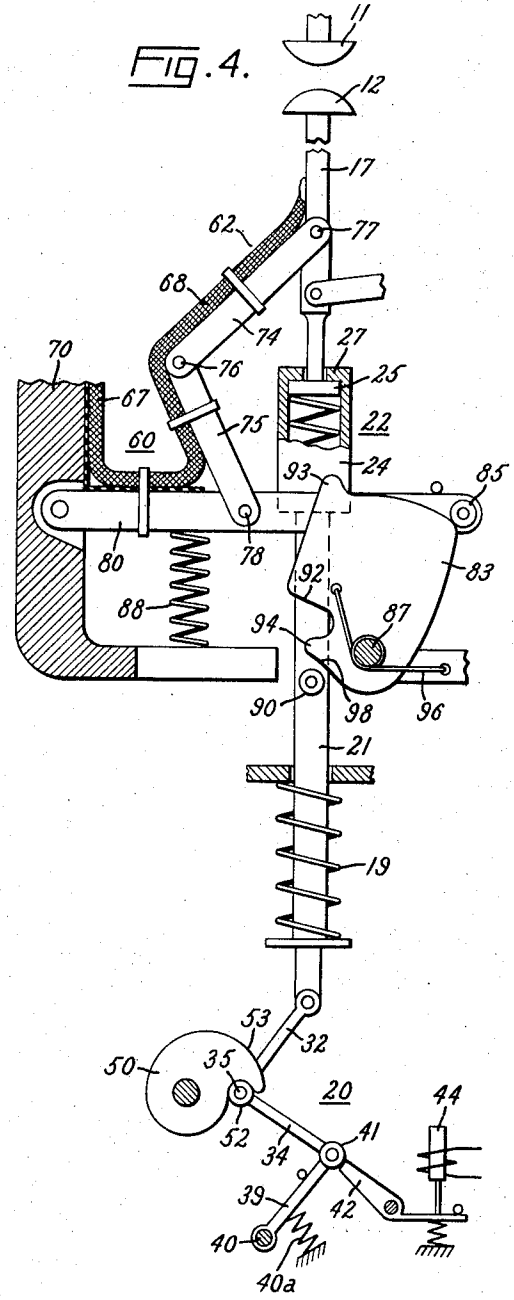
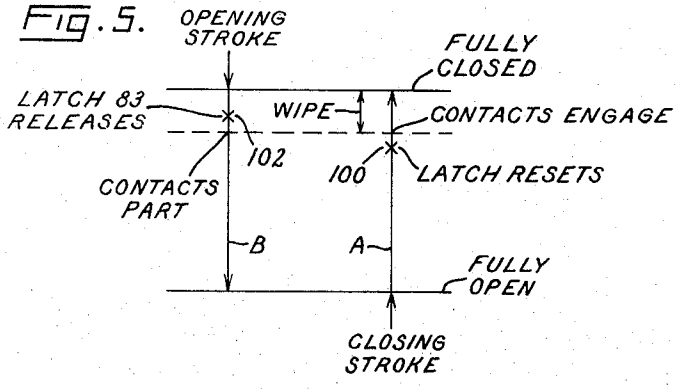


Fig. 5.



INVENTORS:
PHILIP BARKAN,
KLAUS M. SKREINER,
BY William Freedman
ATTORNEY

ELECTRIC CIRCUIT BREAKER WITH MAGNETICALLY ASSISTED CLOSING MEANS

This invention relates to an electric circuit breaker and, more particularly, relates to a circuit breaker that includes electromagnetic means for opposing the magnetic contact-repulsion forces developed when a high current flows through the circuit breaker. This type of circuit breaker is referred to hereinafter as a circuit breaker with magnetically assisted closing means.

In the usual circuit breaker, the conductive path through the contacts of the circuit breaker constricts at the point of contact-engagement and thus contains portions of a generally loop-shaped configuration adjacent the point of contact-engagement. Current flowing through each of these loop-shaped path portions produces magnetic forces tending to enlarge the loop, and these forces are in a direction tending to open the contacts of the breaker. These magnetic opening forces vary in magnitude in accordance with the square of the current flowing through the breaker, and hence during overcurrent and short-circuit current conditions, extremely high magnetic contact-opening forces can be developed. A more detailed explanation of how these magnetic contact-opening forces are developed is contained in U.S. Pat. No. 3,255,160-Barkan, assigned to the assignee of the present invention. Note particularly FIG. 3 thereof.

If a circuit breaker is closed when a fault is present on the line, the above-described high magnetic opening forces are abruptly established near the end of a closing stroke. These forces tend to oppose the final portion of the closing stroke, and it is therefore necessary to provide high closing forces in order to overcome these opposing forces and complete the closing operation. In conventional circuit breakers, the necessity for providing these high forces for closing against short circuits is a major determinant of the size of the closing mechanism and the mechanism-operator. The higher the closing force required, the larger and more powerful the closing mechanism and operator needed.

An object of our invention is to provide a circuit breaker which can be closed against short-circuit currents by a small and relatively weak closing mechanism and mechanism-operator.

One approach toward realizing this objective is illustrated in U.S. Pat. No. 3,366,900-Barkan, assigned to the assignee of the present invention. In the circuit breaker of the Barkan patent, electromagnetic means **40**, **20** or **100**, **20** is provided for developing a closing, or hold-closed, force on the movable contact **12** that varies directly with the square of the current and is present whenever current is flowing through the contacts. While this particular magnetic means does permit a substantial reduction in the closing force required for the closing mechanism **50** and operator, it is subject to the disadvantage that it is difficult with such magnetic means to limit the terminal closing velocity of the movable contact to the desired low value. This is the case because the movable contact **12** is driven into closed position by a closing spring **24** acting directly on the movable contact without any interposed speed-modifying means, such as a closing cam. The closing cam **70** that is present is used for driving part of the closing linkage, but not the movable contact, into a predetermined position; and this motion trips a latch **28** which allows the closing spring **24** to drive the movable contact into closed position.

Another object of the present invention is to provide a magnetically assisted closing mechanism in which the speed of the movable contact is controlled by speed-modifying means such as the closing cam of the usual trip-free closing mechanism.

Another object is to reduce the magnetic forces transmitted to the trip-free mechanism of the breaker and, more specifically, to transmit substantially all magnetic forces directly to a stationary supporting frame through a path that effectively bypasses the trip-free mechanism.

Still another object is to provide a magnetically assisted closing mechanism for a plurality of movable contacts which readily lends itself to the use of a rigid linkage at ground potential for coupling the contacts together to assure synchronized movement of the contacts.

Still another object is to attain each of the above objects with magnetic means that can provide a high closing force for assisting in closing the circuit breaker and holding it closed when desired, but yet does not significantly increase the force required for opening the breaker when such opening is desired.

In carrying out the invention in one form, we provide electromagnetic-assist means for developing a magnetic closing force on the movable contact of the circuit breaker which varies directly in accordance with the current through the contacts. This assist means comprises a substantially rigid support member which when restrained in a fixed position renders the assist means capable of transmitting closing force to the movable contact but which, when released, renders said assist means generally ineffective to transmit closing force to said movable contact. Releasable latching means restrains the support member in said fixed position when the contacts are engaged. For transmitting opening and closing forces to the movable contact, we provide an operating member coupled to the movable contact through a suitable contact-wipe mechanism. Releasing means responsive to travel of the operating member in an opening direction releases the latching means prior to disengagement of the contacts during an opening operation. Restoring means operable following separation of the contacts and completion of an interrupting operation is provided for restoring the latching means to restraining relationship with said support member before the contacts engage during a subsequent closing operation.

For a better understanding of the invention, reference may be had to the following description taken in conjunction with the accompanying drawings, wherein:

FIG. **1** is a side elevational view of a circuit breaker embodying one form of our invention. The circuit breaker is shown in its fully closed position.

FIG. **2** shows the circuit breaker of FIG. **1** in an intermediate position through which it passes during an opening operation.

FIG. **3** shows the breaker of FIG. **1** in another intermediate position through which it passes at a later stage of an opening operation.

FIG. **4** shows the circuit breaker in its fully open position.

FIG. **5** is a diagrammatic representation showing the sequence of certain events during an opening and a closing stroke of the circuit breaker of FIG. **1**.

CIRCUIT INTERRUPTER **10**

Referring now to FIG. **1**, there is shown a circuit interrupter **10** comprising a pair or separable contacts **11** and **12**. Contact **11** is a stationary contact, and contact **12** is a movable contact that is vertically movable into and out of engagement with the stationary contact. In FIG. **1**, the circuit breaker is shown in its fully closed position where contact **12** engages contact **11**. Opening of the circuit breaker is effected by driving contact **12** from its position of FIG. **1** downwardly through its intermediate position of FIG. **3** into its fully open position of FIG. **4**. Closing is effected by returning contact **12** from its position of FIG. **4** to its position of FIG. **1**.

Although this invention, in its broader aspects, is applicable to many different types of circuit breakers, we have shown it embodied in a circuit breaker of the vacuum type. Accordingly, the contacts **11** and **12** are shown located inside a highly evacuated envelope **13** comprising a cylindrical insulated casing **14** and upper and lower end caps **8** and **15** respectively joined thereto by vacuum-tight seals **16**. Stationary contact **11** is mounted on a stationary conductive contact rod **9** that is integrally joined to the upper end cap **8**. Movable contact **12** is mounted on a movable conductive contact rod **17** that projects freely through lower end cap **15**. A flexible metallic bellows **17***a* permits vertical movement of rod **17** without impairing the vacuum inside envelope **13**.

The interrupter is mounted on a stationary frame **70** to which the lower end plate **15** is suitably attached. A suitable guide link **18** is pivotally connected at one end to the frame **70** and at its other end to the contact rod **17**. This guide link coacts with a suitable slide bearing **18***a* to confine motion of the contact rod **17** to a substantially straight-line vertical path.

OPERATING MECHANISM 20, 21, 22 FOR INTERRUPTER

For driving the movable contact **12** upwardly from its fully open position of FIG. **4** into its fully closed position of FIG. **1**, we provide a mechanically trip-free closing mechanism **20** of a suitable conventional form. This closing mechanism **20** is coupled to the movable contact rod **17** by means of an operating rod **21** of insulating material and a wipe device **22** of conventional form located between operating rod **21** and contact rod **17**. Closing is effected by causing the mechanism **20** to drive operating rod **21** upwardly from its position of FIG. **4** into its position of FIG. **1** in a conventional manner soon to be described. Opening, on the other hand, is effected by driving the operating rod **21** downwardly from its position of FIG. **1** by means of an opening spring **19** in a manner soon to be described.

The above-mentioned wipe device **22** comprises a driving part in the form of a cylindrical carriage **24** coupled to operating rod **21** and a driven part in the form of a piston **25** coupled to contact rod **17** and slidably mounted within the bore of cylindrical carriage **24**. Also disposed within the bore of carriage **24** is a precompressed wipe spring **26** which urges piston **25** upwardly toward engagement with an annular stop **27** on the carriage. When carriage **24** is driven in an upward direction from its position of FIG. **4**, piston **25** also moves upwardly, carrying movable contact **12** toward stationary contact **11**. During this closing stroke, precompressed spring **26** holds piston **25** in engagement with annular stop **27** until movable contact **12** engages stationary contact **11**. This engagement between the contacts terminates upward motion of contact **12** and piston **25**, but carriage **24** continues moving upwardly, further compressing spring **26** and separating stop **27** from piston **25** until upward motion of carriage **24** is finally terminated. The distance W moved by the carriage as it travels upwardly after the contacts engage is referred to hereinafter as "wipe" or "wipe-travel." This wipe-travel serves to provide a force that helps to hold the contacts in engagement after closing despite limited wear of the contacts that might have previously occurred. Thus, even if the contacts engage at a slightly later point in the closing stroke because of such contact wear, there will still be some wipe travel after contact engagement; and this will act to make available for holding the contacts closed the force stored in wipe spring **26** and any additional force produced by further compression of the spring during wipe.

Wipe device **22** functions during an opening operation to permit operating rod **21** to move downwardly through the entire wipe distance W while the contacts still remain in engagement. When this wipe travel has been exhausted, stop **27** strikes piston **25** and carries contact rod **16** downwardly with operating rod **21**.

The closing mechanism **20** comprises a pair of toggle links **32** and **34** pivotally joined together at a knee **35**. One of the toggle links **32** is pivotally connected at its opposite end to the lower end of operating rod **21** by means of a pivot pin **36**. The other toggle link **34** is pivotally connected by pivot pin **38** to the upper end of a guide link **39**. Guide link **39** is pivotally supported at its lower end on a fixed fulcrum **40** and is biased toward its position of FIG. **1** by a suitable reset spring **40***a*. The pivot pin **38** carries a latch roller **41** which cooperates with a suitable trip latch **42**, which is normally held in its reset position of FIG. **1** by a reset spring **42***a*. Trip latch **42** is arranged to be operated in response to predetermined circuit conditions by means of a suitable conventional tripping solenoid **44**. Typically, the tripping solenoid **44** is suitably connected to be operated in response to an overcurrent through the power circuit through the breaker. After the solenoid is deenergized, reset spring **42***a* returns latch **42** to its reset position, shown in FIG. **4**.

So long as trip latch **42** remains set, i.e., in its latching position of FIG. **4**, and the guide link **39** is latched by the trip latch, as in FIG. **4**, toggle **32**, **34** is capable of transmitting thrust to movable operating rod **21**. Thus, when knee **35** is driven to the right from its position of FIG. **4**, toggle **32**, **34** is extended and drives operating rod **21** upwardly against the bias of opening spring **19**. FIG. **1** illustrates the position of the parts after knee **35** has been moved to the right to effect complete circuit-breaker closing. This closing motion of knee **35** from its position of FIG. **4** to its position of FIG. **1** is produced by the action of a rotatable cam **50** cooperating with the usual roller **52** which is mounted at knee **35**. When cam **50** is rotated counterclockwise from its position of FIG. **4** to its position of FIG. **1** by a suitable operator (not shown), it drives knee **35** to the right, thereby extending toggle **32**, **34** and driving operating rod **21** and contact rod **17** through their upward closing stroke. At the end of a closing operation, a constant radius portion **53** of cam **50** holds the toggle **32**, **34** in its extended position of FIG. **1** and prevents the toggle from collapsing at its knee **35** so long as trip latch **42** remains in latched position.

Opening of the circuit breaker is effected by tripping latch **42**. This renders the closing mechanism **20** incapable of transmitting continued closing thrust to operating rod **21**. Accordingly, the opening spring **19** quickly discharges to drive operating rod **21** downwardly from its position of FIG. **1** through its position of FIGS. **2** and **3** into its position of FIG. **4**. This motion carries the contact rod **17** downwardly through an opening stroke. The guide link **39** is forced in a clockwise direction about its stationary pivot **40** by such opening motion; but at the end of the opening stroke, when toggle **32**, **34** has collapsed, reset spring **40***a* returns the guide link to its reset position of FIG. **4**, where it is relatched by latch **42**.

Returning now to a closing operation, near the end of the upward closing stroke of movable contact **12**, current will begin flowing through contacts **11**, **12** via a path extending through conductive parts **9**, **11**, **12** and **17**. As pointed out hereinabove, this current produces a magnetic force opposing closing that varies in magnitude directly in accordance with the square of the current. If only a low current flows, then closing mechanism **20** acting alone can provide sufficient force to complete the closing operation against this minor opposition and to maintain contacts **12** and **11** in engagement. But if the current is a high current, then much higher closing forces are needed to complete the closing operation and to maintain the contacts engaged. For providing this supplemental closing force, we rely, in one form of our invention, upon electromagnetic-assist means **60**.

ELECTROMAGNETIC-ASSIST MEANS 60

This electromagnetic-assist means **60** comprises a flexible conductor **62** of a loop-shape form connected in series with the contacts **11**, **12**. One end of the flexible conductor **62** is suitably connected to contact rod **17** at **63**, and the opposite end is connected at **64** to a copper terminal stud **65**. Flexible conductor **62** is preferably of copper braid. The arm **67** and the stud **65** are fixed to a stationary supporting framework **70**. This supporting framework **70** is preferably of a low conductivity metal so that substantially all current flows through the arm **67** of the copper braid without entering framework **70**. Most of the rest of the braid **62** is physically connected to other parts of the electromagnetic-assist means **60**, as will soon be explained. Suitable local insulation is provided, however, to confine the primary current path to the braid **62**.

The electromagnetic-assist means **60** further comprises a toggle comprising two toggle links **74** and **75** pivotally joined together at a knee **76**. Upper toggle link **74** has its upper end pivotally connected to contact rod **17** by a pivot pin **77**. Lower

toggle link **75** has its lower end pivotally mounted at **78** on a toggle support lever **80**. Toggle support lever **80** has one end pivotally mounted on a fixed pivot **82** carried by frame **70**. The opposite, or free, end of toggle support lever **80** is restrained in its position of FIG. **1** by a releasable latch **83** that cooperates with a latch roller **85** carried by lever **80**. A suitable stop **86** prevents counterclockwise motion of lever **80** past its position of FIG. **1**. The latch **83**, which is pivoted on a stationary pivot **87** carried by frame **70**, will soon be described in more detail.

Returning now to the flexible conductor **62**, the lower portion of this conductor is mechanically connected to the toggle support lever **80**, and the arm **68** is mechanically connected to the two toggle links **74** and **75**. Current flowing at any given instant through the loop-shaped conductor **62** passes in opposite directions through the two arms **67** and **68**, developing magnetic fields around the two arms that interact in a known manner to produce a repulsive magnetic force F that urges the arms apart. This repulsive magnetic force varies directly with the square of the current passing through the loop-shaped conductor. The effect of this repulsive magnetic force is to urge the toggle **74**, **75** toward an in-line or extended position, thus developing a force on the contact rod **17** that acts in an upward closing direction. The geometry of the toggle **74**, **75** is preferably such that the electromagnetic repulsion force between the two arms **67** and **68** is multiplied by a factor of 2 or 3. Thus, when high currents flow through contacts **11**, **12** to produce a contact separating force, a larger than proportional closing force is developed by the magnet-assist means **60** to oppose the contact-separating force. Toggle linkage **74**, **75** is a highly efficient arrangement for producing this desirable force-multiplying effect.

Since the braid **62** is relied upon for carrying the current through magnetic-assist mechanism **60**, it will be apparent that no current need be carried by the pin joints of the mechanism. This enables the mechanism to be of a less expensive design since no current-carrying, rotating joints need be employed therein.

If the expense of current-carrying joints can be accepted, such joints may be used in the toggle **74**, **75** and the toggle made of a highly conductive metal such as copper or suitable copper alloy so that current can be carried directly therethrough via a path of the same general shape as the illustrated arm **68**, but without reliance upon the braid. The toggle itself would then constitute the arm **68**, and the magnetic repulsive force F would be exerted directly on the toggle without being transmitted through any braid.

It is noteworthy that both the contact-separating magnetic force and the magnetic-assist force vary as the square of the current. Since the design is such that the magnetic-assist force is greater than the contact-separating force, the magnetic-assist force automatically stays above the contact-separating force irrespective of the extend that the current rises, assuming, of course, that the magnetic-assist means is not in its disabled condition described hereinafter. Although this is a preferred relationship, it is only necessary that the sum of the wipe spring force and the magnetic-assist force exceed the contact-separating force at all currents within the rating of the breaker.

DISABLING THE ELECTROMAGNETIC-ASSIST MEANS 60

Not infrequently, the circuit breaker will be called upon to open while high currents are flowing therethrough. To prevent interference with such opening by the closing force developed by the magnetic-assist means **60** during such high current conditions, we provide means for effectively disabling the magnetic-assist means **60** during this period. This disabling means comprises the releasable latch **83** and means responsive to opening movement of operating rod **21** for releasing latch **83** to free the toggle-support lever **80** for clockwise motion about its pivot **82**. When toggle support lever **80** is thus free, the toggle **74**, **75** is no longer capable of imparting substantial closing force to contact rod **17**. Accordingly, during this period, the repulsive magnetic force developed between arms **67**, **68** of the loop-shaped conductor and urging the toggle toward an in-line position acts primarily to drive the lever **80** downwardly rather than to exert a closing force on contact rod **17**. FIG. **3** illustrates the behavior of the magnetic-assist means **60** during this period when it is disabled. In FIG. **3**, latch **83** is shown released, and the toggle support lever **80** is moving in a downward, or clockwise, direction against the action of a relatively weak reset spring **88**. When latch **83** has been released, the opposition of the magnetic-assist means **60** to opening can be no greater than that offered by relatively weak reset spring **88**. With only this minor opposition to overcome, opening can take place at the desired high speed.

For controlling the latch **83** of magnetic-assist means **60** in response to motion of operating rod **21**, a pin **90** is provided on the operating rod for cooperating with the latch **83**. When the circuit breaker is in its closed position of FIG. **1**, pin **90** is located in an enlarged notch **92** in latch **83**. During circuit-breaker opening, when the operating rod is driven downwardly by opening spring **19**, pin **90** engages a projecting nose **94** on latch **83** and drives latch **83** counterclockwise about its pivot **87**. FIG. **2** shows the parts after the downward moving pin **90** has driven latch **83** counterclockwise to the point at which the latch is just ready to release the toggle-support lever **80**. When pin **90** passes downwardly through the position of FIG. **2**, the counterclockwise moving latch **83** releases the toggle support lever **80**, and lever **80** moves clockwise toward its position of FIG. **3**, driven by the magnetic repulsion force F. Downwardly moving pin **90** eventually moves past the nose **94**, at which time latch **83** resets to its position of FIG. **4** under the influence of a latch-reset spring **96**. Latch-reset spring **96** is so constructed that it returns the latch in a clockwise direction to a neutral position just short of where it would be effective to latch the toggle-support lever **80**. When current through the circuit breaker is interrupted, the force F depicted in FIG. **3** disappears, and toggle-support lever **80** returns to its position shown in FIG. **4** under the influence of reset spring **88**. Lever **80** is not latched in this position, however, since latch **83** is then being held by its reset spring **96** in the above-described neutral position where it is ineffective to latch lever **80**.

It is desirable that lever **80** remain unlatched when the circuit breaker is fully open because this retains the magnetic-assist means **60** in a disabled condition and thus prevents an inadvertent closing of the circuit breaker in response to any electrical breakdown between the contacts **11**, **12** which might result in a resumption of current through the circuit breaker. If lever **80** was in a latched condition during the passage of such current, the magnetic-assist means **60** would develop a closing force which would return the contacts to closed position. In most applications, such closing would be undesirable. If circuit-breaker closure under such conditions is desired or can be tolerated, then it is satisfactory to allow latch **83** to reset to a latching position with respect to toggle support lever **80** when the circuit breaker is fully open and an interrupting operation has been completed.

RESETTING THE MAGNETIC-ASSIST MEANS DURING CLOSING

As previously pointed out, a closing operation is performed by driving closing cam **50** counterclockwise from its position of FIG. **4** into its position of FIG. **1**, thereby extending toggle **32**, **34** of the closing mechanism **20** and driving operating rod **21** upwardly. After operating rod **21** has traveled through a predetermined part of the closing stroke, pin **90** on the upwardly moving operating rod engages the lower surface **98** of nose **94** on latch **83**, thereby pivoting latch **83** clockwise from its position of FIG. **4** to force the latch into a latching position beneath roller **85** on toggle-support lever **80**. (A projecting tip **93** on the latch **83** prevents the latch from overtraveling in a

clockwise direction in response to impact from the upwardly moving pin **90**.) During the remainder of the closing travel of operating rod **21**, pin **90** holds latch **83** in latching relationship with the roller **85** on the toggle support lever. The position of these parts at the end of a closing stroke is illustrated in FIG. **1**. During the above-described upward closing travel of operating rod **21**, pin **90** moves upwardly past nose **94**, causing latch-reset spring **96** to pivot latch **83** counterclockwise; but pin **90**, which is then positioned in notch **92**, limits such counterclockwise motion of latch **83** sufficiently to maintain the latch in latching relationship with roller **85** on toggle support lever **80**.

During a closing operation, it is important that the latch **83** be restored to its latching position prior to the instant at which current flow through the contacts is reinitiated. This can be accomplished if the latch is restored to its latching position prior to the point of contact engagement, with a slight margin allowed for a possible restrike between the contacts when they are close together just prior to reaching engagement. This timing is illustrated in the diagram of FIG. **5**, where it can be seen that during the closing stroke A, the latch resets at a point **100** just preceding contact-engagement. The reason for this timing is that unless the latch is reset, the magnetic-assist means **60** remains disabled and therefore unavailable to provide the supplemental force that would be needed under high current conditions for closing against the magnetic opposing force developed as soon as current flow is resumed. But with the latch reset before the point at which current flow is resumed, the magnetic-assist means **60** is available to supply the required supplemental closing force as soon as current flow is resumed.

TIMING THE DISABLEMENT OF THE MAGNETIC-ASSIST MEANS DURING OPENING

During the opening stroke, it is important that the latch **83** be released prior to the point at which the contacts part. Otherwise the magnetic-assist means **60** would be developing a hold-closed force at the time of attempted contact-part that could defeat, or detract from the speed of, contact separation. By releasing the latch **83** prior to the point of contact-part, e.g., at **102** in FIG. **5**, we render the magnetic-assist means **60** incapable of supplying a substantial closing force at the time the contacts separate, thus allowing the contact to separate without substantial interference from the magnetic-assist means **60**. For achieving this timing, we make latch-release responsive to motion of the operating rod **21**. Since the operating rod **21** moves through its wipe travel prior to contact separation, we can use this motion to trip latch **83** before the point of contact part is reached. FIG. **2** best illustrates this relationship, showing how downward opening motion of the operating rod **21** is in the act of releasing latch **83** while some wipe travel at **104** is still needed before the contacts will part.

GENERAL DISCUSSION

One important advantage of our invention is that our magnetic-assist means **60** is usable with an operating mechanism **19, 20, 21, 22** that is of an essentially conventional design. This permits existing components to be used for such operating mechanism. But with the magnetic-assist means **60** present, the operating mechanism can be used in circuit breakers with a much higher momentary and interrupting current rating than it could be used in without the magnetic-assist means.

Because we are able to rely upon an operating mechanism **19–21** of essentially conventional design, we are able to retain most of the advantageous features present in the conventional design, e.g., mechanically trip-free performance and a simple closing cam which can be driven by conventional means such as an electric motor or spring.

Another significant advantage of our overall mechanism is that we are able to precisely control the contact-closing velocity and to limit the terminal closing velocity to a relatively low value suitable for vacuum interrupter contacts. In this respect, we use the usual closing cam **50** for controlling velocity, and by suitably contouring this cam **50** we can provide whatever closing velocities are desired.

Another advantage of our mechanism is that it does not rely on any sort of latch for holding its contacts open when the circuit breaker is open. This function is performed by the opening spring **19**, and no reliance is had upon either of the latches **83** or **42** for this hold-open function. By avoiding any need for relying upon a hold-open latch, we assure that latch failure does not cause inadvertent closing of the contacts.

Another advantage of our mechanism is that it is readily usable in circuit breakers that comprise a plurality of sets of contacts which must be mechanically coupled together for operation in synchronism. For example, in a three-phase circuit breaker which has one interrupter in each phase operated by a single operating mechanism, such as **20**, common to all three phases, the coupling between the phases can be achieved with a rigid linkage of conventional design at ground potential connected between the lower ends of the operating rods. An example of such a coupling is shown at **92, 95** in U.S. Pat. No. 3,163,735-Miller, assigned to the assignee of the present invention. With such an interconnecting linkage present, there is a substantially rigid coupling between the contact structures of the three phases. The wipe device **22** in each phase has some resilience but during the crucial stages of contact-motion this resilience is negligible.

Where interrupters in series are used, it is a simple matter to connect operating rod **21** to the contact structures of the other interrupters by means of a rigid linkage that synchronizes motion of all the series-connected interrupters and permits their operation from a single operating mechanism such as **20**. An example of such a linkage is shown in U.S. Pat. No. 3,418,439-Casey at al., assigned to the assignee of the present invention.

Still another advantage of our overall mechanism is that the reaction forces developed by the magnetic-assist means **60** are not transmitted to the closing mechanism **20** or operating rod **21**. Such forces are transmitted directly to the rigid stationary frame **70** through a force-transmitting path tat bypasses these latter components. In this respect, note that the reaction force that the toggle **74, 75** exerts on toggle-support lever **80** is transmitted to frame **70** through latch **83** and completely bypasses the operating rod **21** and closing mechanism **20**. Similarly, the magnetic repulsion force exerted on the arm **67** of the loop-shaped conductor **62** is transmitted directly to stationary frame **70**, against which it bears, without reaching the operating mechanism **20** or operating rod **21**.

While the forces due to the wipe spring **26** and the opening spring **19** are still transmitted to the closing mechanism **20**, as in conventional designs, these forces are easily accommodated in our mechanism because these springs (**26** and **19**) are much weaker than corresponding springs in conventional designs of the same momentary or interrupting current rating. This is the case because these springs can be selected without regard to the high magnetic contact-separating forces developed by high currents through the breaker. These high magnetic forces are now borne primarily by the magnetic-assist means **60** and not by the wipe spring **26** or by the operating rod **21** or closing mechanism **20**.

Because we are able to use a weaker wipe spring, we subject the contacts to much lower impacts during closing against light currents or no current than would be the case if the usual much heavier wipe spring was relied upon. In addition, since the closing force from our mechanism **20** is much lower than in conventional mechanisms, which supply the same high closing force for all currents, there is less closing force supplied by our mechanism during no-current or light-current closing to produce heavy impacts between the contacts. By reducing the severity of such impacts, we can increase the life of the contacts and other components of the interrupter, such as its seals and bellows.

Because our closing mechanism **20** and operating rod **21** are no longer required to withstand the magnetic contact-separat-

ing forces (which are now borne by the magnetic-assist means **60**), they can be much less massive than before. This reduced mass not only reduces their cost but also enables them to operate at higher speeds and with shorter response times, thus permitting faster circuit-breaker opening.

Our magnetic-assist means has the additional advantage of reducing contact-bounce upon closing. The hold-closed force supplied by the magnetic-assist means **60** at the instant of contact-engagement is in opposition to the bounce and thus tends to suppress it. While the extra mass added to the contact rod by the presence of the magnetic-assist means does detract somewhat from the bounce-suppressing ability of the magnetic-assist means, we are able to limit this detracting effect because our toggle adds relatively little effective mass compared to the mass that would be added by other comparable mechanisms capable of developing a corresponding magnetic closing force.

While we have shown and described a particular embodiment of our invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from our invention in its broader aspects; and we, therefore, intend herein to cover all such changes and modifications as fall within the true spirit and scope of our invention.

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

1. An electric circuit breaker comprising:

a. a first contact,

b. a second contact movable into engagement with said first contact to close said circuit and movable out of engagement with said first contact to open the circuit breaker and interrupt the circuit therethrough,

c. electromagnetic-assist means for developing a magnetic closing force on said movable contact which varies directly in accordance with the current through said contacts,

d. said electromagnetic-assist means comprising a substantially rigid supporting member which when restrained in a fixed position renders said electromagnetic-assist means capable of transmitting closing force to said movable contact but which, when released, renders said electromagnetic assist means generally ineffective to transmit closing force to said movable contact,

e. releasable latching means for restraining said supporting member in said fixed position when said contacts are engaged,

f. an operating member for transmitting opening and closing forces to said movable contact,

g. a wipe mechanism coupling together said operating member and said movable contact and permitting limited overtravel in a closing direction of said operating member after said contacts engage during a closing operation and also permitting limited travel of said operating member in an opening direction before opening force is transmitted from said operating member to said movable contact,

h. releasing means responsive to travel of said operating member in an opening direction for releasing said latching means prior to disengagement of said contacts during an opening operation,

i. and restoring means operable following separation of said contacts and completion of an interrupting operation for restoring said latching means to restraining relationship with said supporting member before said contacts engage during a subsequent closing operation.

2. The circuit breaker of claim **1** in which said restoring means operates in response to travel of said operating member in a closing direction to restore said latching means to restraining relationship with said supporting member before said contacts engage during a closing operation.

3. The circuit breaker of claim **1** in which said electromagnetic-assist means comprises:

a. a toggle having one end coupled to said supporting member and its opposite end coupled to said movable contact independently of said operating member, said toggle imparting a closing force to said movable contact when forced toward an in-line position,

b. conductive means in series with said contacts for carrying current through a loop-shaped path that comprises a pair of series-connected arms between which a repulsive magnetic force is developed that urges said arms apart when current traverses said loop-shaped path,

c. and means for forcing said toggle toward an in-line position when said arms are urged apart by said repulsive magnetic force.

4. The circuit breaker of claim **1** in which said electromagnetic-assist means comprises:

a. conductive means in series with said contacts for carrying current through a loop-shaped path that comprises a pair of series-connected arms between which a repulsive magnetic force is developed that urges said arms apart when current traverses said loop-shaped path,

b. and means connected between said supporting member and said movable contact for converting said repulsive magnetic force into said magnetic closing force on said movable contact.

5. The circuit breaker of claim **4** in which said means connected between said supporting member and said movable contact comprises a toggle that is forced toward an in-line position by said repulsive magnetic force, said toggle exerting said magnetic closing force on said movable contact when urged toward an in-line position.

6. The circuit breaker of claim **1** in which:

a. said releasable latching means comprises a latch and means biasing said latch toward a non-latching neutral position located near where the latch becomes effective to latch said supporting member,

b. said releasing means allowing said latch to return to said neutral position at a point in the opening operation near the end of opening travel of said operating member,

c. means operable when high currents cease to flow through said circuit breaker for returning said supporting member to substantially the position where it is normally restrained by said latching means,

d. and said restoring means of (i)-claim **1** is responsive to closing travel of said operating member to return said latch from said neutral position to a latching position with respect to said supporting member during a closing operation.

7. The circuit breaker of claim **1** in which:

a. said releasable latching means comprises a latch and means biasing said latch toward a non-latching neutral position,

b. said restoring means comprises latch-control means coupled to said operating member for encountering said latch and forcing said latch into a latching position in response to closing travel of said operating member prior to contact engagement,

c. said latch is shaped to allow said latch to return partially to said non-latching neutral position in response to further closing motion of said operating member after the latch-control means initially encounters said latch,

d. said latch-control means prevents said biasing means from forcing said latch into non-latching neutral position during closing travel of said operating member following the initial encounter with said latch, thereby maintaining said latching means in restraining relationship with said supporting member during said latter travel.

8. The circuit breaker of claim **7** in which said latch is shaped so as to cause said latch-control means to effect latch-release in response to opening motion of said operating member prior to the transmission of opening force from said operating member to said movable contact.

9. The circuit breaker of claim **1** in which:

a. there is further provided a trip-free mechanism that is coupled to said movable contact through said operating member, and

b. said latching means is so located that the reaction force produced by said electromagnetic-assist means in developing said closing force is transmitted to said latching means via a force-transmitting path that bypasses said trip-free mechanism.

10. An electric circuit breaker comprising:

a. a first contact,

b. a second contact movable into engagement with said first contact to close said circuit breaker and movable out of engagement with said first contact to open the circuit breaker and interrupt the circuit therethrough,

c. electromagnetic-assist means for developing a magnetic closing force on said movable contact which varies directly in accordance with the current through said contacts,

d. said electromagnetic-assist means comprising a substantially rigid supporting member which when restrained in a fixed position renders said electromagnetic-assist means capable of transmitting closing force to said movable contact but which, when released, renders said electromagnetic-assist means generally ineffective to transmit closing force to said movable contact,

e. releasable latching means for restraining said support-ing member in said fixed position when said contacts are engaged,

f. a circuit-breaker closing mechanism,

g. operating structure for transmitting closing force from said closing mechanism to said movable contact via a force-transmitting path that bypasses said electromagnetic-assist means,

h. means for supplying an opening force to said movable contact to effect a circuit-breaker opening operation,

i. means operable during said circuit-breaker opening operation for releasing said latching means prior to disengagement of said contacts during said opening operation,

j. and restoring means operable following separation of said contacts and completion of an interrupting operation for restoring said latching means to restraining relationship with said supporting member before said contacts engage during a subsequent closing operation.

11. The circuit breaker of claim 10 in which said restoring means for restoring said latching means to restraining relationship with said supporting member effects said restoration during a closing operation.

12. The circuit breaker of claim 11 in which said restoring means is responsive to travel of said operating structure in a closing direction.

13. The circuit breaker of claim 10 in which said closing mechanism is a trip-free mechanism that is coupled to said movable contact through said operating structure in such a manner that the speed of operation of said mechanism determines the speed with which the movable contact moves into engagement with said first contact during circuit-breaker closing.

14. The circuit breaker of claim 10 in which:

a. said closing mechanism is a trip-free mechanism that is coupled to said movable contact through said operating structure, and

b. said latching means is so located that the reaction force produced by said electromagnetic-assist means in developing said hold-closed force is transmitted to said latching means via a force-transmitting path that bypasses said trip-free mechanism.

15. The circuit breaker of claim 10 in which said electromagnetic-assist means comprises:

a. a toggle having one end coupled to said supporting member and its opposite end coupled to said movable contact, said toggle imparting a closing force to said movable contact when forced toward an in-line position,

b. conductive means in series with said contacts for carrying current through a loop-shaped path that comprises a pair of series-connected arms between which a repulsive magnetic force is developed that urges said arms apart when current traverses said loop-shaped path,

c. and means for forcing said toggle toward an in-line position when said arms are urged apart by said repulsive magnetic force.

16. The circuit breaker of claim 10 in which:

a. said operating structure comprises:

i. an operating member through which said opening force is transmitted to said movable contact, and

ii. a wipe mechanism for coupling said operating member to said movable contact in such a manner that said operating member is free to move in an opening direction before initiating contact-separation,

b. and there is provided means responsive to opening motion of said operating member before said contacts disengage for effecting said release of said latching means prior to disengagement of said contacts.

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