Aug. 4, 1970 A. BIANCHI ET AL 3,523,261

CURRENT LIMITING CIRCUIT BREAKERS

Filed Jan. 30, 1968 7 Sheets-Sheet 1

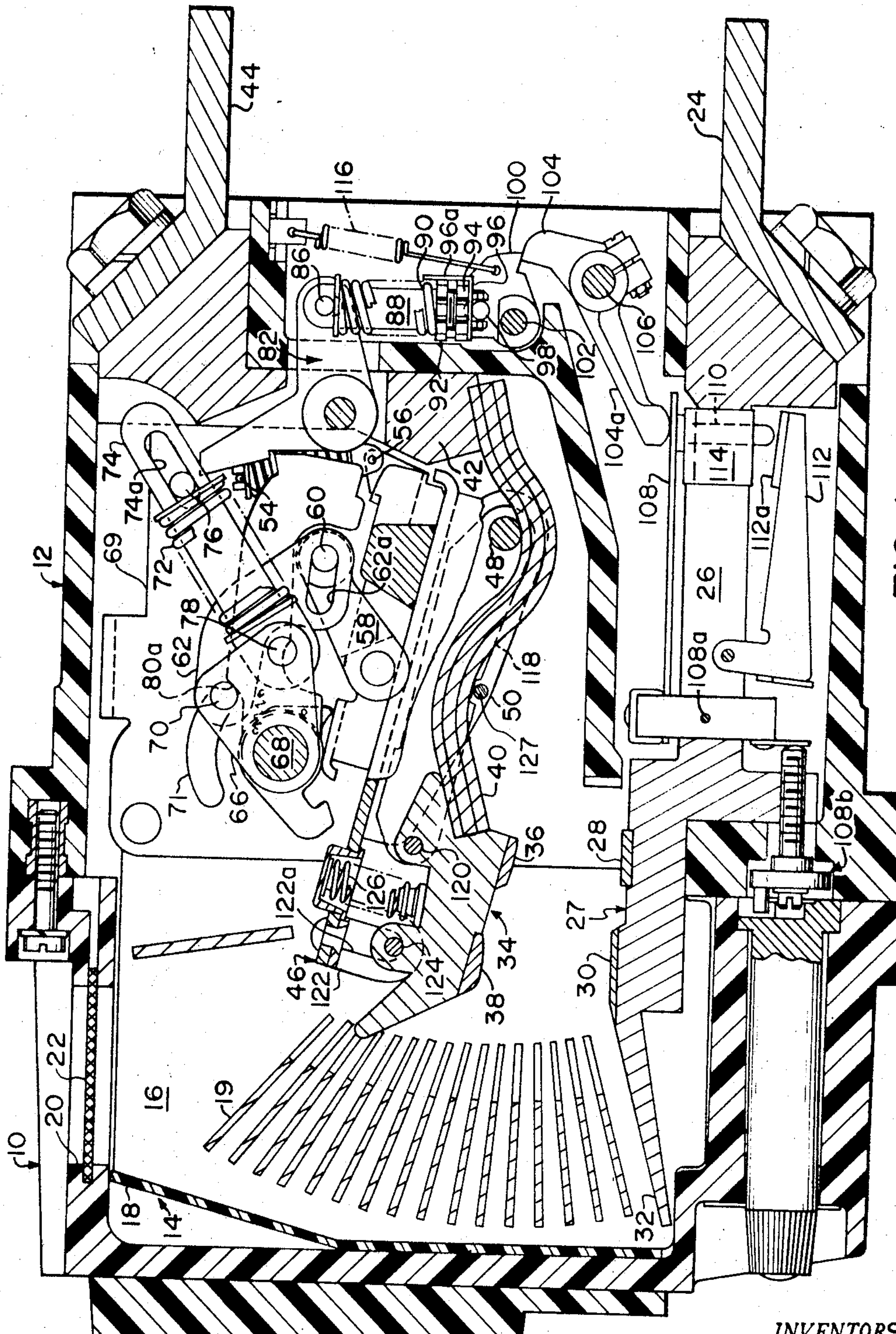

FIG. 1

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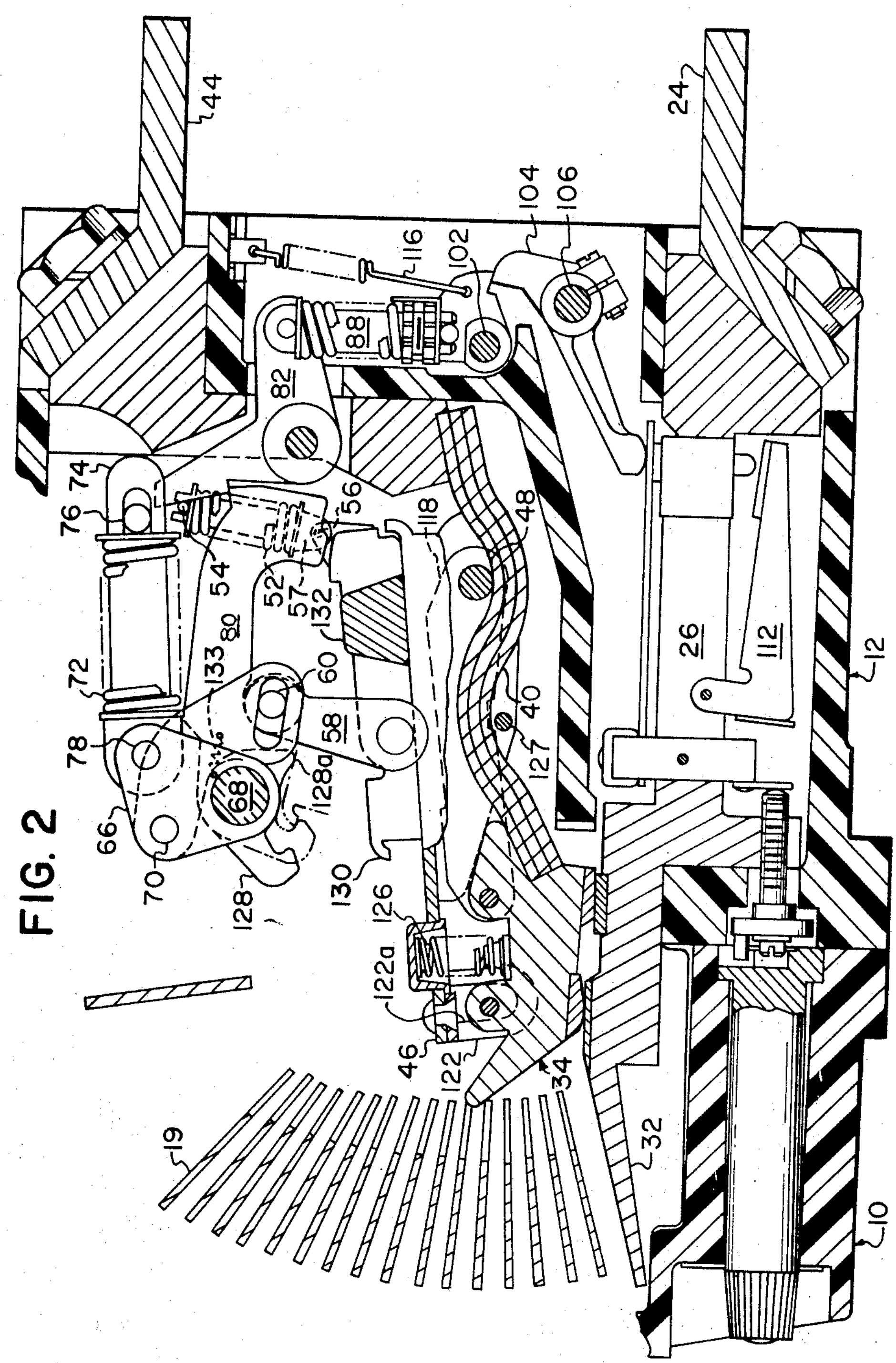

FIG. 2

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CURRENT LIMITING CIRCUIT BREAKERS

Filed Jan. 30, 1968 7 Sheets-Sheet 3

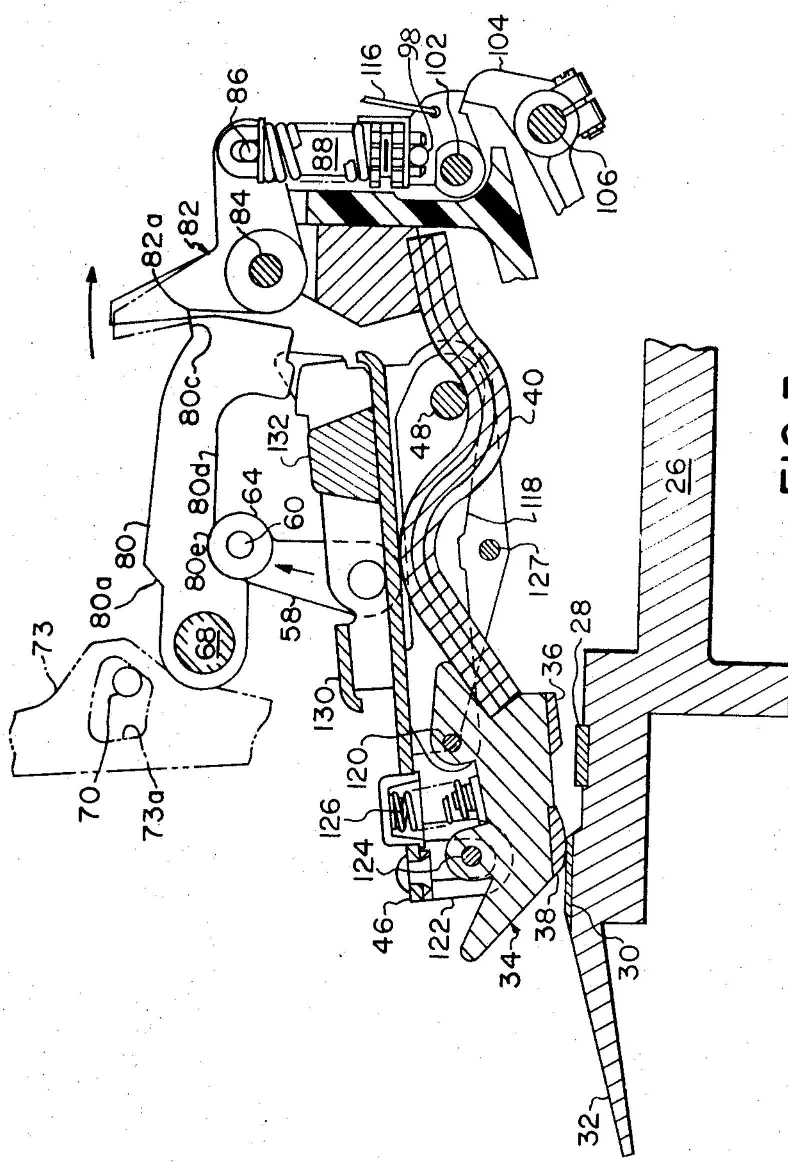

FIG. 3

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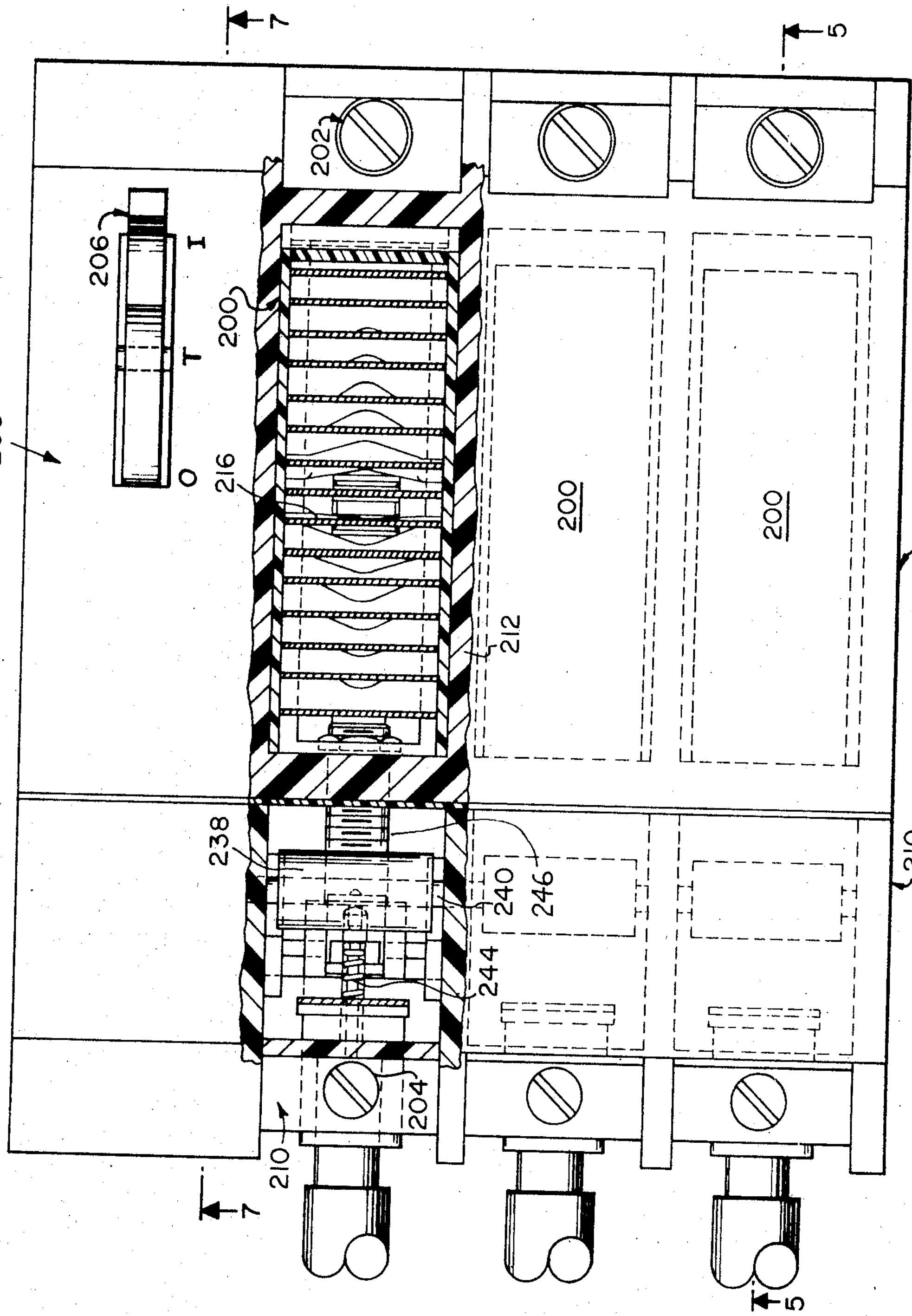

FIG.4

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CURRENT LIMITING CIRCUIT BREAKERS

Filed Jan. 30, 1968 7 Sheets-Sheet 5

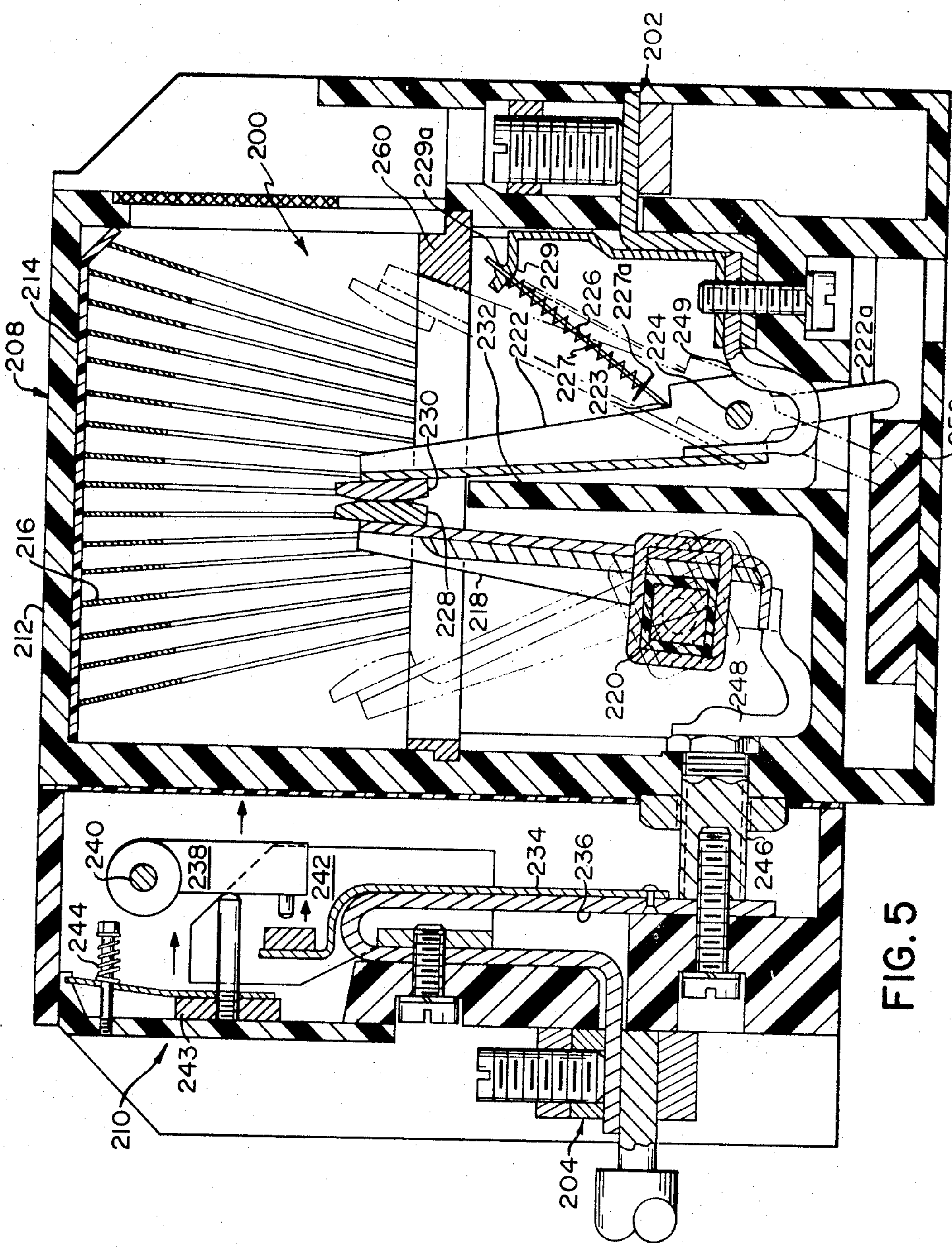

FIG. 5

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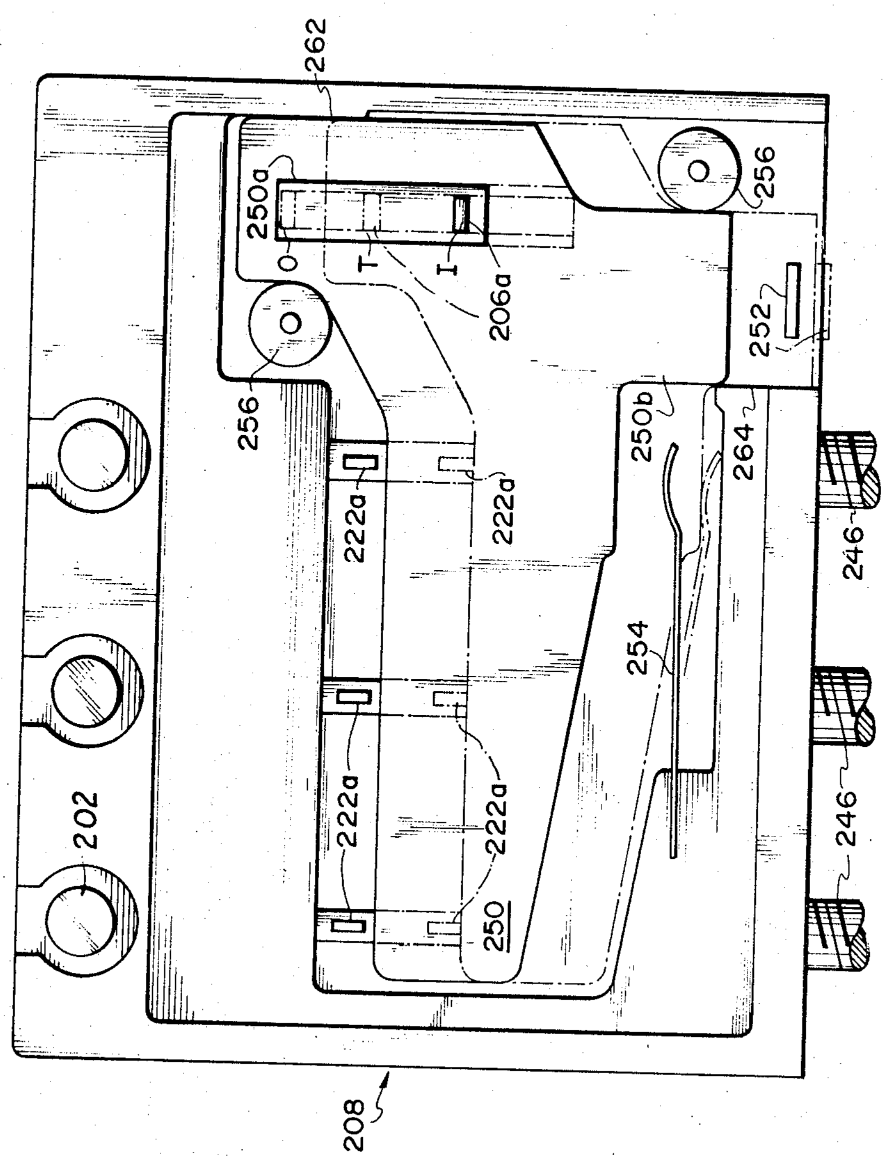

FIG. 6

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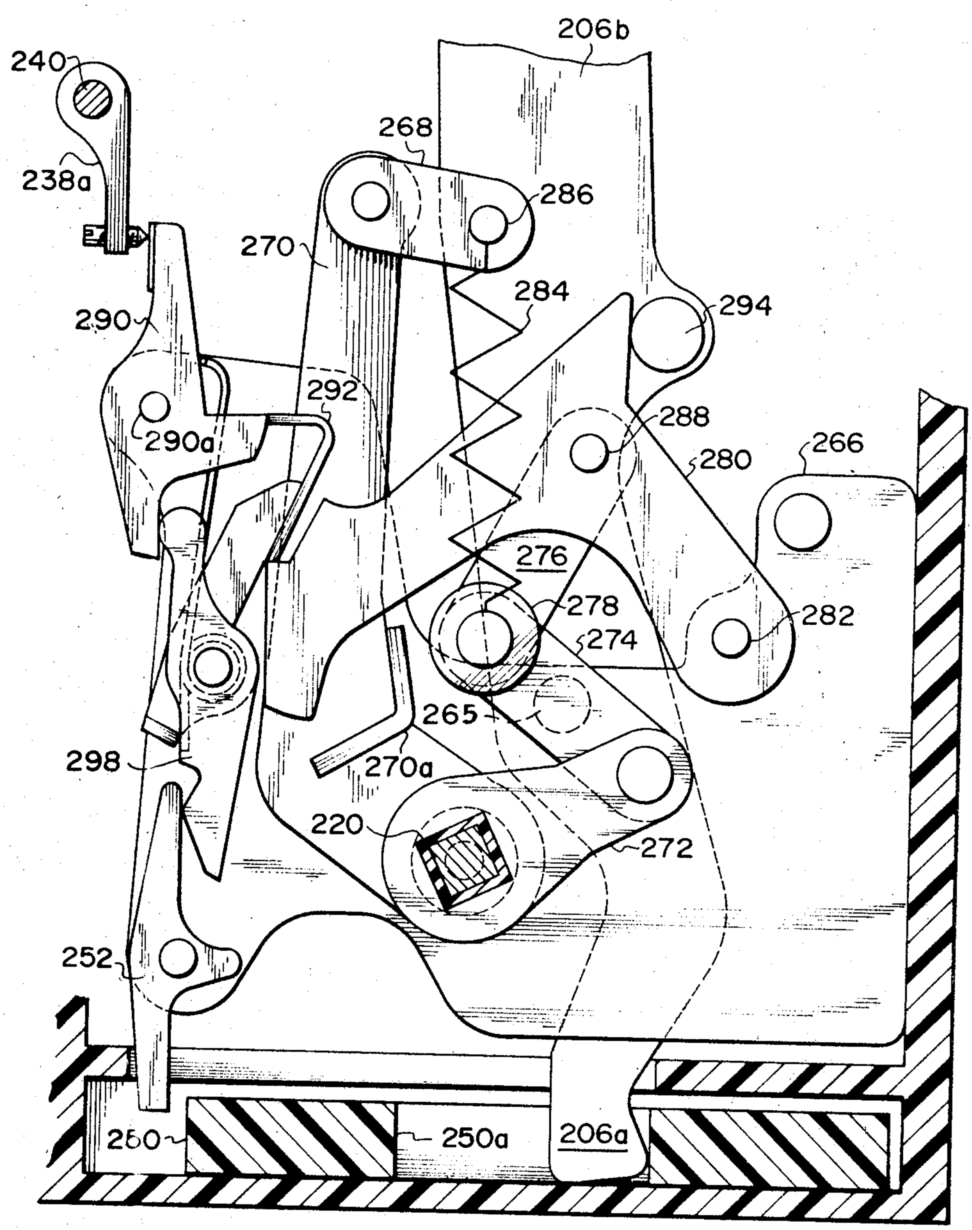
FIG. 7



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CURRENT LIMITING CIRCUIT BREAKERS

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Int. Cl. H01h 77/10
U.S. Cl. 335—16 8 Claims

ABSTRACT OF THE DISCLOSURE

A circuit breaker with high interruption capacity is realized by utilizing an electromagnetic loop that expands instantly when high current develops, to part the contacts initially and to cause continued contact-opening motion to full fault-current interruption. Responsiveness to the electrodynamic force is preserved and adequately large contacts are utilized without the corresponding consequence of contact-parting bounce at the instant of closing, by providing a gradual contact-closing operation that is completed with a short, sudden motion. In one form, the contact which is operated with minimum bounce to close the circuit breaker is also the contact that is moved electrodynamically to open the breaker; and in this construction the electrodynamic force unlatches the breaker-opening mechanism. In the other form, one contact is actuated to close the contacts and the companion contact is electrodynamically operable for opening the circuit breaker.

The present invention relates to circuit breakers. An object of this invention is to provide circuit breakers of novel construction having relatively high interruption capacity. This capacity is needed where the circuit breaker is connected to an electric bus or cable that is capable of delivering extremely high levels of current under short-circuit conditions.

A further object of the invention is to provide novel circuit breakers which can be made in comparatively small physical proportions, which are nevertheless capable of interrupting remarkably high currents in case of short-circuit.

A still further object of the invention is to provide a novel circuit breaker which will open and safely clear the circuit in response to severe short-circuit, where the short-circuit exists at the time that the circuit breaker is closed, and also in response to a short-circuit that occurs at some time after the circuit breaker is closed.

The invention has broad application, but it is particularly applicable to circuit breakers of the class having an enclosure of molded insulation. Furthermore, it is particularly applicable to so-called low-voltage circuit breakers, that is, circuit breakers rated at 600 volts or less.

The novel circuit breakers can be constructed in various physical sizes and with various operating mechanisms, to open automatically when the current exceeds the overload calibration. Such a circuit breaker may be rated at any value, usually at a value in the range of 15 amperes to 1,200 amperes. These circuit breakers (of whatever current rating) should have a vastly greater current-interruption capacity.

Two novel forms of circuit breakers in realizing the foregoing objects are represented in the accompanying drawings and described in detail below. In both examples there is a "blow-off" configuration of the current path to and from the contacts, and in both examples there is an operating mechanism that closes the contacts in a motion

that is slow at first and then becomes sudden so that the contacts close firmly and without hesitation.

The "blow-off" current path includes a current loop which tends to expand mechanically when a short-circuit occurs and this effect is used to cause instant separation of the contacts.

The high-speed blow-off contact-opening feature is an important factor in providing current-limiting characteristics. Where the circuit breaker opens the circuit fast enough, in a properly proportioned arc chute, the rise of current is limited to only a fraction of the current capacity of the bus. The interruption process is made much easier than in circuit breakers that do not limit the rise of current.

The tendency of the loop to expand is due to the electrodynamic force that develops at the instant that a short circuit occurs. This effect is utilized to cause opening of the contacts under short-circuit conditions. In order to obtain full advantage of the blow-off construction, it is important to avoid appreciable mechanical bouncing or rebounding of the contacts as they close. Otherwise the bouncing of the contacts might be a substitute for electrodynamic force in unintentionally causing the contacts to open. Furthermore, bouncing of the contacts would interfere with the sudden increase in current in case a short-circuit exists at the time the circuit breaker is closed, and interference with the current rise would interfere with the electrodynamic contact-opening force that is needed to limit the rise of current. The novel circuit breakers are operated into closed position with firm closing force by a mechanism that operates the moving contacts gradually through most of the closing stroke, followed by a sudden short motion that completes the closing of the contacts, without interfering with the electrodynamic contact-opening feature.

One of the circuit breakers described below is especially adapted to operate at relatively high rated-current levels, and to withstand particularly high short-circuit current levels. The current-carrying parts are made large, to handle the high rated currents. The contact structures and the electrodynamic release mechanism in this circuit breaker for causing the contacts to open involve further novel features of the invention.

Pursuant to one feature of this form of circuit breaker, the moving contact is made of two parts, a main contact part and an arcing contact part. When the circuit breaker is in its closed condition, the main contact part is pressed firmly against the companion contact. In case of a short-circuit the electrodynamic force developed by the reverse-current loop acts to lift the main contact part. High contact pressure is maintained and even increased at the arcing contact part. The arrangement is such that the arcing contact will not break the circuit unless the electrodynamic force is great enough to release a latch which restrains a spring-biased contact-opening mechanism. When the mechanism is released, the circuit breaker opens at high speed, far enough to clear the circuit. The electrodynamic force first unlatches the contact-opening mechanism and then the electrodynamic force directly increases the contact-opening force of the contact-opening spring. Because the arcing contacts remain closed until the opening mechanism is unlatched there is no possibility of small arcs developing between contacts that open slightly and then close again. Without this feature, such a condition could exist in case of large currents that are not large enough to release the opening mechanism. The arcing could damage the contact surfaces, and could result in the contacts becoming welded together.

Circuit breakers of this construction operate in the contact opening direction with a great deal of speed. The moving contact structures of such circuit breakers are massive when designed to carry high currents. A massive moving contact structure having a high contact-opening speed normally tends to rebound powerfully in the contact-closing direction as soon as it reaches the limit of the opening motion. A further features of this invention resides in providing a simple, effective and reliable antirebound latch for the moving contact structure.

In the second form of current-limiting circuit breaker there is also a "blow-off" configuration of the current path to and from the contacts, and there is also an operating mechanism that closes the contacts in a motion that is slow at first and then becomes sudden so that the contacts close firmly and without hesitation. Certain additional objects and advantages are realized in the second embodiment. A maximum separation of the contacts is realized, an advantage in assuring reliable interruption of the arc under all conditions. Also, even though it is possible for only one pole of the circuit breaker to open electrodynamically (due to short-circuit current in only one pole) nevertheless there is provided a reset mechanism that guarantees closing of the contacts in all the poles when the circuit breaker is operated subsequently.

The foregoing general discussion of some of the novel features of the invention will be understood better by considering the drawings and the following detailed description.

In the drawings:

FIG. 1 is a lateral cross section through the center pole of a multipole circuit breaker involving one embodiment of certain features of the invention, the circuit breaker being shown with the contacts open;

FIG. 2 is a fragmentary cross section of the circuit breaker in FIG. 1 with the contacts shown closed, and with antirebound latching parts shown in broken lines to represent an instantaneous relationship thereof during opening of the breaker;

FIG. 3 is another fragmentary cross sectional view of the circuit breaker in FIG. 1 illustrating certain parts while under the influence of electrodynamic force and including a manual operating lever in broken lines;

FIG. 4 is a plan view, partly in cross section, of a second circuit breaker constituting another illustrative embodiment of certain aspects of the invention;

FIG. 5 is a vertical cross section of the circuit breaker viewed from the plane 5—5 in FIG. 4 with portions thereof shown in broken lines to illustrate the positions thereof assumed during a short-circuit interrupting operation;

FIG. 6 is a bottom view of the circuit breaker in FIGS. 4 and 5 as seen with a cover removed; and

FIG. 7 is a lateral view of the operating mechanism as viewed from the plane 7—7 in FIG. 5.

The circuit breaker shown in FIGS. 1 to 3 includes an enclosure or case formed of parts of molded insulation including parts **10** and **12**. Part **10** contains an arc chute **14** which has side walls **16** and end wall **18** of fibre or other suitable arc resistant insulating material, supporting an assembly of V-notched arc splitter plates **19** of magnetizable metal. The arc chute and part **10** of the molded enclosure have a vent opening **20** which is shielded by a wire-mesh barrier **22** secured in grooves in molded part **10**.

The electric circuit through the illustrated pole of the circuit breaker includes a terminal **24** and an elongated conductor **26** carrying stationary contact structure **27** comprising stationary main contact **28** and stationary arcing contact **30**. Arcing horn **32** extends from contact **30** into arc chute **14**. Movable contact member **34** includes a main contact part **36** and an arcing contact part **38**. Elements **28**, **30**, **36** and **38** are of suitable material such as silver-tungsten. A flexible elongated conductor **40** as of laminated copper, provides a current path from movable contact member **34** to a fixed block **42**, and to terminal **44**.

In the closed condition of the circuit breaker (see FIG. 2) a current loop is formed of conductor **40**, movable contact **34**, the companion contact **27** and conductor **26**. Conductors **26** and **40** carry currents in opposite directions, and are called "reverse current paths." These parts repel each other electrodynamically when they carry current.

Movable contact **34** is carried by an arm or contact carrier **46** which is essentially channel shaped, opening downward. Arm **46** is pivoted on a supporting shaft **48** which extends through the side walls **50** of the channel. A compression spring **52** (FIG. 2) on guide rod **57** works against pivot **56** on contact carrier **46**, and the opposite end of this spring presses against a fixed pin **54**. Multiple springs like spring **52** may be used at opposite sides of the mechanism, only one spring being shown. Pivot **56** of spring **52** approaches the line of centers of pin **54** and shaft **48** as the contacts close, but pivot **56** does not reach this line of centers. Spring **52** provides opening bias for arm **46** about shaft **48** when the arm is in its open position. When arm **46** is in the contacts-closed position, spring **52** is compressed further, but the opening force is not greatly increased because the line of the spring force is closed to pivot **48**.

The operating mechanism for arm **46** includes a link **58** having one end pivoted to arm **46** and having a pin **60** at its opposite end. Pin **60** moves in a slot **62*a*** of another link **62**. Pin **60** also carries a roller **64** (see FIG. 3).

A heavy triangular operating member **66** is fixed to a stationary shaft **68** rotatably mounted in side plates **69**. There are two side plates **69** at opposite sides of the mechanism. Shaft **70** extends into slots **71** in the side plates. Movement of shaft **70** to the right is limited by the right-hand ends of slots **71**. Shaft **68** is rotated and member **66** is operated to the right and to the left for opening and closing the circuit, by means that is diagrammatically represented in FIG. 3. As shown there, a manual lever **73** has a large opening **73*a*** that receives shaft **70** to drive the pin in each direction. The arrangement is such that shaft **70** is not restrained and can overtravel when snapping operation occurs, as will be described.

Shaft **70** connects member **66** to link **62**. Compression spring **72** has a guide rod **74** whose slot **74*a*** works along fixed pin **76**. Pin **78** connects the opposite end of guide rod **74** to member **66**.

Latch member **80** is pivoted on shaft **68** and has an upper edge portion **80*a*** (FIG. 3) that is engaged by shaft **70** in the open condition of the circuit breaker (FIG. 1). Latch member **80** has a latch portion **80*c*** that is pressed down under a hook portion **82*a*** of latch **82** when the circuit breaker is open, for relatching. Latch **82** restrains latch member **80** when the circuit breaker is closed. Member **80** also has an edge **80*d*** constituting a bearing rail for roller **64**. A slight depression **80*e*** in member **80** establishes a stable end position in the leftward travel of roller **64**, so that the roller is arrested in the position illustrated in FIG. 3 when the circuit breaker is closed.

Latch **82** is carried on a fixed pivot **84** and has an arm carrying a pin **86**. Rod **88** has a slotted upper portion which receives pin **86**; best shown in FIG. 3. The lower end of rod **88** is cylindrical and it is threaded, and it terminates in a slotted portion which fits about pin **98**. Compression spring **90** on rod **88** is confined between pin **86** and a nut **92** adjustable on rod **88**. Another nut **94** on rod **88** provides an adjustable lower end for rod **88** to bear against pin **98**. Nuts **92** and **94** have many notches around their edges, and these nuts are held in any adjusted position by bending a tongue **96*a*** of washer **96** into such notches.

Pin **98** is carried by a latch part **100** which moves about a pivot **102**. In FIG. 1 pin **98** is shown slightly to the right of a line between the centers of pivots **86** and **102**. Spring **90** normally maintains pins **98** and **86** in the extended condition illustrated so that parts **86**, **88**, **90**, **92**, **94** and **96** act as if they were a simple link under normal conditions. This link transmits a force from latched member **80** pressing latch **82** clockwise (FIG. 2) to apply latch pressure of latched part **100** against latch **104**.

Latch **104** has an arm **104a** that can be lifted by upward movement of bimetal **108**. Independently, latch arm **104a** is operable by upward movement of a rod **110** that is slidable in a bore in member **26**. A U-shaped soft iron core **114** extends across the top of conductor **26** and has downward extending legs. Opposite core **114** is a soft iron armature **112a** carried by a pivoted arm **112**.

A persistent moderate overcurrent in conductor **26** causes heating sufficient to deflect bimetal **108** upwardly for releasing latch parts **100** and **104**.

Bimetal **108** has a support pivot **108a** and an adjusting structure **108b** for externally accessible adjustment of the "thermal" tripping-current level. In the event of a more severe overcurrent, armature **112a** is lifted so that pin **110** pushes arm **104a** to release latch **104** and latch parts **100** in response to "magnetic" tripping-current levels. In case of either magnetic tripping or a thermal tripping, latch **104** swings clockwise to release latched part **100**. Thereafter the parts **88–90–92–94–96–98** act as a unit to swing latch part **100** clockwise about its pivot. Release of latch **104** releases latched part **80** (FIG. 2) and this allows link **58** and the entire contact assembly to swing upward due to the bias of contact-pressure spring **126** and, thereafter, compression spring **52**. Reset of latched part **80** is accomplished by clockwise rotation of triangular member **66**, which drives shaft **70** against the portion **80a** of part **80**, returning the mechanism to the configuration in FIG. 1. Latch **82** and unit **88** . . . **98** and **100** are reset by the bias of tension spring **116** which engages latched part **100** (FIG. 1). Latch **104** is reset by a suitable weak spring (not shown).

Moving contact **34** has two pins **120** and **124**. Pin **124** is received in a pair of slots **122a** in a downward-facing channel element **122**. Moving contact **34** is biased downward by compression spring **126**. A pair of links **118** pivoted to shaft **48** support pin **120**, and links **118** are arrested (against bias of spring **126**) by stop **127** fixed to the side walls **50** of downward-facing channel **46**.

Spring **126** bears against contact **34** between the two pins **120** and **124**. In the closed condition of the contacts, both contact parts **36** and **38** bear against the companion contacts **28** and **30**, pin **124** being spaced away from the lower edges of slots **122a**. In the closing motion of contact **34**, contact part **38** engages contact part **30** first and the main contacts **36** and **28** engage thereafter. In the opening motion, contact parts **28** and **36** separate first so that arcing occurs only at parts **30** and **38**.

When the circuit breaker is closed, a current loop is provided by conductor **26**, contacts **27** and **34**, and flexible conductor **40**. The current loop includes reverse current paths in parts **26** and **40**. In case of a short circuit, this current loop tends to expand under enormous electrodynamic force, and the parts assume the configuration in FIG. 3 almost instantantly. Flexible conductor **40** lifts contact **36**. Links **118** as well as conductor **40** bear against channel **46** with great force. During this motion spring **126** continues to exert great downward force, maintaining contact at arcing contacts **30** and **38**. The electrodynamic force pushes contact arm **46** upward against link **58**, applying a powerful bias to lift member **80**, but no motion of arm **46** has occurred thus far.

There is a slight push-off angle at engagement point **80c**, **82a**, which provides an enormous reverse "mechanical advantage." This means that a very large upward force applied by member **80** to latch **82** causes only a very small force tending to rotate latch **80** clockwise. This force is opposed by spring **88** acting on latch **82**. When the electrodynamic force (greatly reduced by the effect of the push-off angle at **80c**, **82a**) overcomes the restraining effect of spring **88** on latch **82** (see FIG. 3), latched part **80** is released and the contact arm **46** is driven upward electrodynamically at high speed. There is no delay in the unlatching operation, only a measuring of the opening force as against the required unlatching force. If the force is not adequate to release latch **82**, contact part **36** may lift somewhat. No arcing occurs, inasmuch as arcing contact part **38** firmly maintains a circuit between moving contact **34** and companion contact **26** until the latch **82** is released.

In case the contact arm should be released and driven upward there is danger of impact at its upward limit followed by rebound downward toward the companion contact **26**. To avoid any such effect, an antirebound latch **128** is provided having a tail **128a** that is struck by a hooked part **130** at the top of contact arm **46**. This drives latch **128** into dotted-line position in FIG. 2. Part **130** is hooked by latch **128** and prevents arm **46** from rebounding downward. When the breaker is closed spring **133** biases tail **128a** to an advanced position as shown in solid lines in FIG. 2 slightly clockwise of the position of FIG. 1, so as to be struck by part **130** when the arm **46** comes close to its full-open position.

The foregoing circuit breaker is operative as a single pole device or with multiple poles tied together and linked by mechanically coupled trip units, in various ways well known in the art.

When operating member **66** is being moved from the position in FIG. 1 to that in FIG. 2, link **62** initially draws shaft **60** toward the left and progressively drives link **58** in the direction to swing contact arm **46** downward. As this motion continues, pivot **78** swings upward about shaft **68** and approaches the lines of centers of shaft **68** and pin **76**. Shortly after pin **78** passes this line of centers, spring **72** provides an abrupt further motion to member **66** in the counterclockwise direction, thereby suddenly completing the travel of pin **60** to drive roller **64** to the position shown in FIG. 3.

The circuit breaker illustrated is of a physical design suitable for carrying large amounts of rated current, for example, 1000 amperes, and accordingly the various current carrying parts may well be relatively large and massive. Consequently, when the circuit breaker is being closed there would be a tendency of the movable contact arm to rebound after striking the companion contact structure **26**. Such a rebound involves an upward reaction force tending to release the latch **82** from latched part **80**, in this manner simulating the electrodynamic force that develops when the circuit breaker is subjected to high levels of short-circuit current. Such large impact and rebound forces are avoided here by virtue of the action of the contact-closing mechanism described above which operates in the closing direction to carry the movable contact structure gradually through most of its operating stroke. The completion of the closing stroke is accomplished suddenly when pin **78** crosses the line of centers between shaft **68** and pin **76**. Thus the contact-closing motion is completed with a short sudden motion and the contact-closing operation is firm and without hesitation.

The action of the electrodynamic force which occurs under short circuit conditions may develop at a time when the circuit breaker has been closed or it may exisit before the circuit breaker is operated to close the contacts. In any case, the sudden appearance of the electrodynamic force is such that contact opening motion is extremely fast, occurring during the sudden rise of the short-circuit current. This operation takes place within a small part of a half-wave, in the case of 60-cycle alternating-current circuits. With a properly proportioned arc chute, current interruption occurs in such a manner as to limit the rise of current well below anything that might be expected in circuit breakers of other construction, in which no current limiting action occurs. As a result the interruption process does not await the normal end of the half-cycle during which contact opening occurred.

Instead the arc is suppressed and the current is interrupted before waiting for the alternating current wave to pass through zero.

Referring now to FIGS. 4 to 7, another form of circuit breaker is shown as a second illustrative embodiment of certain features of the invention found in the circuit breaker of FIGS. 1 to 3 and including additional novel features. In FIG. 4 the circuit breaker shown involves three side-by-side poles having an arc chute **200** and a pair of terminals **202** and **204** in each pole; and at one end of the unit there is an operating mechanism generally designated **206**. The circuit breaker is divided into a current-interrupting unit **208** which includes the arc chutes and the separable contacts (to be described) and the operating mechanism, plus a second unit **210** which includes the overload sensing devices for the respective poles, and a coupling arrangement to control the operating mechanism **206**.

Section **208** (FIG. 5) includes a housing portion **212** of insulation containing an arc chute involving a fibre "wrapper" **214** and a plurality of ferrous V-notched arc splitter plates **216**. A movable contact arm **218** is shown in its fully closed position, held in this position by shaft **220**. This shaft is common to all of the poles and is insulated from each of the contact arms **218**. A companion contact arm **222** on pivot **224**, individual to each pole, is biased by a compression coil spring **226** in the closing direction so that contacts **228** and **230** are in firm pressure contact with each other. In this condition, both contact arms **218** and **222** are out of engagement with a dividing wall **232** of insulation, integral with housing **212**. Coil spring **226** is guided along a metal strip **227**. One end of the spring presses against a disc **227*a*** fixed to strip **227**, and the other end of spring **226** presses against bracket **229**. Strip **227** slides loosely in a slot in bracket **229**. The other end of strip **227** is pressed into a notch **223** in arm **222**. In the closed condition of the contacts, spring **226** acts on strip **227** along a line that passes above pivot **224** and in this way spring **226** provides firm contact pressure.

The overload sensing structure **210** in each pole includes a bimetal **234** which moves to the right when heated by a current-carrying conductor **236** of limited cross section. An overcurrent deflects bimetal **234** to the right sufficiently to operate trip lever **238** about common trip bar **240**. This trip bar extends to the mechanism **206**. A magnetic core **242** having a transverse portion encircled by conductor **236** is disposed to attract an armature **243** in the event of sudden high levels of overcurrent well above the tripping level of bimetal **234**. Motion of armature **243** is resisted by a coil spring **244**. When there is a sufficient overcurrent, armature **242** moves to the right and operates trip bar **240**.

A circuit may be traced through the pole represented in FIG. 5 starting at terminal **204**, through conductor **236**, conductive stud **246**, and a flexible conductor **248**, through contact arms **218** and **222**, then through flexible conductor **249**, to opposite terminal **202**.

In the event of a mild overload, bimetal **234** deflects trip bar **240** after a substantial delay (depending on the severity of the overcurrent) and for higher levels of excess current, armature **243** operates trip bar **240** in the tripping direction, with faster response.

In the event of a sudden current of short circuit proportions, the current loop extending through arm **218**, contacts **228** and **230**, and arm **222** constitutes an electrodynamic loop tending to drive arm **222** clockwise about its pivot **224**. At this time contact arm **218** is mechanically held in the "closed" position by the operating mechanism **206**. However, the force of spring **226** is overcome by the electrodynamic force, and arm **222** moves toward its dotted-line position. As this happens, the line of action of spring **226** changes. At one moment this line extends through pivot **224**, which is a centered position. From the start until this moment, the compression of spring **226** increases but the effective force of the spring in the contact-closing direction decreases and becomes zero when strip **227** extends along a line through pivot **224**. The inertia of arm **222** which is in motion, and a residual amount of electrodynamic force, carry spring **226** past the centered position and then spring **226** forces arm **222** to complete the opening motion to stop **260**. This is a second stable resting position of arm **222**.

When the short-circuit appears, armature **243** drives trip bar **238** in the direction to release the operating mehcanism of contact arm **218**, and this arm moves to its dotted-line position. This occurs after a short delay following the high-speed motion of contact arm **222**. The great separation between contact arms **218** and **222** in their dotted-line positions provides a further guarantee that any persisting arc will be interrupted.

FIGS. 5 to 7 show the operating mechanism for contact arm **218**, and also show two additional features, (1) the mechanism for resetting arms **222** to prepare the circuit breaker for reclosing, and (2) a mechanical arrangement for tripping the circuit breaker in case any arm **222** is opened electrodynamically.

Each of the contact-carrying arms **222** has an extension **222*a*** acting on an insulating material plate **250** (FIG. 6) which is freely slidable between the rollers **256**, the latter being pivoted on fixed axes, and guided by flat surfaces **262** and **264**.

Said plate **250** has a slot **250*a*** receiving the extension **206*a*** of the manual operating lever of the breaker.

When at least one contact-carrying arm **222** is rotated clockwise by electrodynamic forces, its extension **222*a*** acts upon the plate **250** and shifts the latter to the position shown in dotted lines, overcoming the bias of the spring **254**.

During progress of said shift, the plate **250**, by means of its extension **250*b***, induces the rotation of lever **252** and the latter, via a linking mechanism which is shown in FIG. 7, acts like trip bar **240** on a latching mechanism described below, and thus opens the circuit breaker.

The contact **228** is thus brought to the position shown in dotted lines. Concurrently, the operating lever of the circuit breaker, set free by the trip mechanism, is brought to the upper end of the slot **250*a***, a position connoted by "T."

Said position of the operating lever, intermediate between those taken as the circuit breaker is open "O" and closed "I," indicates that the circuit breaker has been opened by automatic release action. See FIGS. 4 and 6.

To restore the contacts **230** to their position shown in solid lines part **206*a*** of the manual operating lever is moved to the open breaker position "O."

In so doing, the operating mechanism is reset and, concurrently, the extension **206*a*** is moved and shifts the plate **250**. The latter, in turn, moves the extensions **222*a*** of the contact-carrying arms **222** so that contacts **230** are brought back to their position as shown in solid lines in FIG. 5.

The circuit breaker cannot be closed if even a single contact of the contacts **230** is in the position indicated in dotted lines, since the two actions, relatching of the operating mechanism and moving the contacts **230** to the position required for closing the circuit breaker take place simultaneously.

In the case of a very high overcurrent, electrodynamic forces develop in the loop formed by arm **218**, contacts **228–230** and arm **222**, which tend to swing the arm **222** clockwise about its pivot **224**. At this stage the contact-carrying arm **218** is mechanically retained in the closed position by the operating mechanism **206**. When the electrodynamic forces are such as to overcome the contrary bias of spring **226**, the arm **222** is rotated clockwise and the contacts **230** are driven away from the contacts **228**.

The separation of the contacts and of the contact-carrying arms gives rise to a decrease in the electrodynamic forces acting on the arms **218** and **222**. Said decrease is countered, at least in the first stage of movement, by the fact that the current is still increasing under usual short-circuit conditions, in spite of the insertion in the loop of the resistance due to the arc.

Simultaneously, as has been seen, there is a decrease of the counter-torque due to the spring **226**: for this reason, the movement of the arm **222**, once it has been started, is irreversible, and the contact **230** is stopped only when it reaches the second equilibrium position as determined by the abutment **260**.

As has been observed, the clockwise rotation even of a single one of the arms **222** also causes the opening of all the contacts **228**.

The result is that, as a consequence of an abrupt overcurrent, both the contacts **228** and **230** take the position shown in dotted lines.

FIG. 7 shows details of a suitable operating mechanism for contact arms **218** on shaft **220**, and for elements **206***a* and **252** in FIG. 6. Note that FIG. 7 shows the mechanism in the open condition of the circuit breaker. Manual lever **206***b* has a fixed pivot **265** in metal frame **266**. Lever **206***b* drives link **268** to operate a secondary operating lever **270** about a bearing on shaft **220** but lever **270** does not operate shaft **220** directly.

Arm **272** fixed to shaft **220** is pivoted to a toggle link **274**. Another toggle link **276** is pivoted to link **274** at the "knee" of the toggle, and a roller **278** is carried on this pivot. The upper end of link **276** is pivoted to a member **280**, which has a fixed pivot **282** in the frame. Tension coil spring **284** hooks on a pin **286** on manual level **206***b*, and spring **284** biases the knee of the toggle upward.

This linkage is shown in the normal "open" position of the circuit breaker. To close the circuit breaker, manual lever **206***b* is moved to the right. A part **270***a* of secondary lever **270** reaches roller **278** and pushes this roller, in the direction to straighten toggle links **274** and **276**, and driving arm **272** and the contact-arm shaft **220** in the closing direction gradually. During this motion of manual lever **206***b*, spring **284** gradually changes its line of action until this line crosses the top pivot **288** of the toggle. After that point is passed, the toggle is operated by spring **284** in a sudden motion, moving roller **278** away from part **270***a*. Contacts **228** close suddenly against contacts **230**. This gradual motion of the contact arms **218** through most of the closing stroke, followed by a sudden but short motion to complete the closing stroke, is important for preventing bouncing of the contact arms **222** as already explained.

FIG. 7 shows trip arm **238***a* that is operated by bimetal **234** or armature **243** (FIG. 5) in case of an overload. Arm **238***a* moves to the right for tripping the circuit breaker, and operates secondary latch **290** on its pivot **290***a*, and releases latch **292** to release member **280** in the usual manner. Toggle spring **284** can then cause arm **272** to open the contacts. Later, manual level **206***b* is forced toward the left to operate reset pin **294** for resetting parts **280**, **292** and **290** to the condition shown, the described release mechanism and contact-opening mechanism is entirely conventional.

FIG. 7 shows the connection of extension **206***a* (FIG. 6) to the manual lever **206***b*. When the top of lever **206***b* moves to the right to close the circuit breaker, extension **206***a* moves freely in slot **250***a*. Later, in case any one of the contact arms **222** open electrodynamically, plate **250** is shifted to the left in FIG. 7 and strikes lever **252**. This operates another lever **298**, to release latch **290**. So long as any arm **222** remains in its "open" position, plate **250** and lever **252** act to prevent relatching of the circuit breaker, as previously explained in connection with FIG. 6. This arrangement prevents a dangerous condition. To reset arms **222** it is only necessary to move manual lever **206***b* in the direction to reset the latch mechanism, because in this motion tail **206***a* drives plate **250** in the direction to reset contact arms **222**. It is notable that this arrangement provides for resetting of arms **222** without in any way interfering with the maximum open condition of the contact arms **218** and **222** as shown by dotted lines in FIG. 5. Plate **250** is a mechanical coupling to the automatic release mechanism of the circuit breaker, and is important because it assures opening of all the contacts **228** in case of a short circuit. Plate **250** supplements the action of armature **243**. In case no armature or bimetal is used, plate **250** is the only automatic control for releasing all the contacts **228** to open when any one or more of the contacts **230** are opened electrodynamically.

What we claim is:

1. A circuit breaker of high interrupting capacity, including a pair of terminals and means including a movable contact and a companion contact providing a current path interconnecting said terminals, and mechanism for operating the movable contact to open and close the circuit breaker, characterized in that said current path includes a blow-open loop tending instantly to enforce opening movement of one of the contacts by electrodynamic force in response to sudden high levels of current, said circuit breaker having means normally effective when the circuit breaker is closed to hold the contacts closed and said means being operable by said electrodynamic force for causing opening operation of the circuit breaker to its current-interrupting configuration, and further characterized in that said mechanism for operating said movable contact includes means for operating the movable contact gradually in the contact-closing direction followed by a short sudden contact-closing motion, for quickly and firmly closing the contacts with a minimum of mechanical bounce and thereby avoiding interference with the operation of the blow-open current loop.

2. A circuit breaker in accordance with claim **1**, further characterized in that the movable contact includes an arcing contact part and a main contact part, the latter normally being pressed against the companion contact, said blow-off loop being arranged to lift the main contact part by electrodynamic force, and means for converting the electrodynamic force that lifts the main contact part into a force that presses the arcing contact part against the companion contact.

3. A circuit breaker in accordance with claim **2**, in which the circuit breaker includes companion main contact parts and companion arcing contact parts, further characterized in that the operating mechanism includes a contact-opening spring and a latch that is releasable by expansion of the blow-off loop for causing continued opening movement of the main contact part and instantly causing high-speed opening of the arcing contact part.

4. A circuit breaker in accordance with claim **1**, wherein the contact that is moved electrodynamically has a means for holding it in its open position, and wherein the operating mechanism has an instantaneous release mechanism to move the other contact to its open position so that both contacts move away from their closed positions in case of short circuit.

5. A circuit breaker in accordance with claim **4**, wherein said automatic release mechanism has a mechanical coupling to the electrodynamically operated contact for insuring release operation.

6. An automatic circuit breaker in accordance with claim **4**, including means for resetting said electrodynamically operated contacts and additionally for resetting the automatic release mechanism of the circuit breaker.

7. A circuit breaker in accordance with claim **1** including a latch having a hook portion cooperable with the moving contact structure thereof to arrest return motion thereof toward the companion contact and a biasing spring normally holding the hook portion out of such cooperation, said latch having a portion disposed to be struck by the moving contact structure as the limit of its opening motion is reached for impelling the hook portion into position to arrest the moving contact structure against said return motion.

8. A circuit breaker in accordance with claim 3 including a latch having a hook portion cooperable with the moving contact structure thereof to arrest return motion thereof toward the companion contact and a biasing spring normally holding the hook portion out of such cooperation, said latch having a portion disposed to be struck by the moving contact structure as the limit of its opening motion is reached for impelling the hook portion into position to arrest the moving contact structure against said return motion.

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