Oct. 25, 1949. D. I. BOHN 2,486,104

CIRCUIT BREAKER

Original Filed July 28, 1942 5 Sheets-Sheet 1

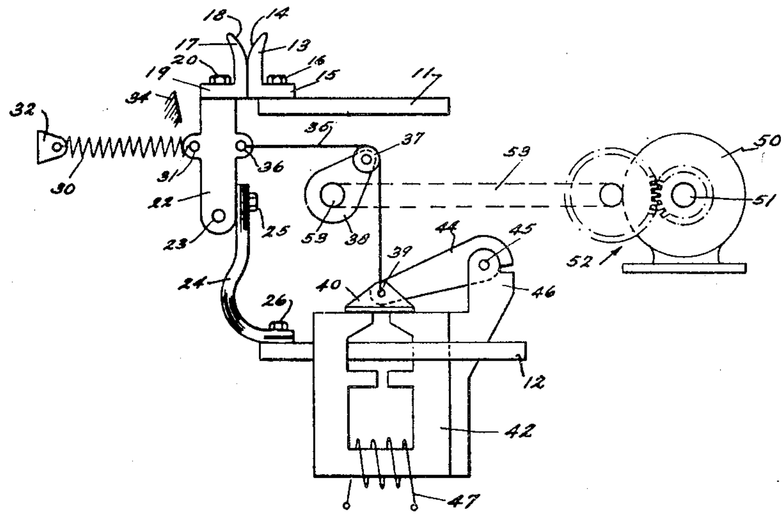

Fig. 1

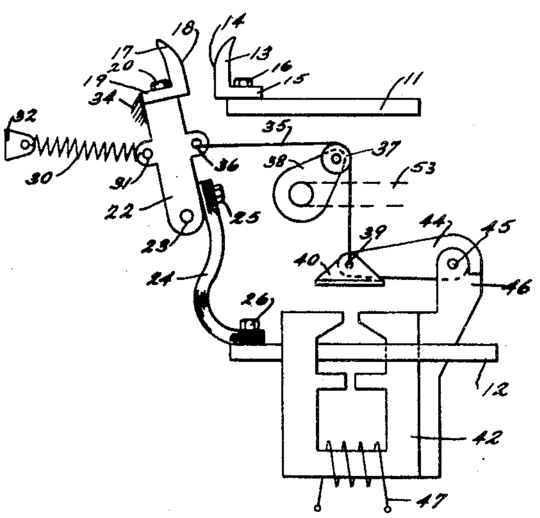

Fig. 2

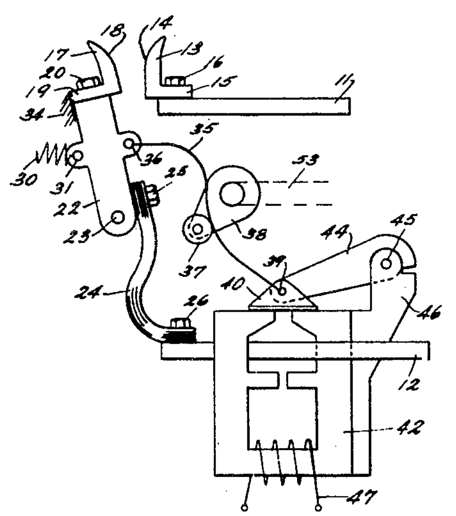

Fig. 3

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Original Filed July 28, 1942 5 Sheets-Sheet 2

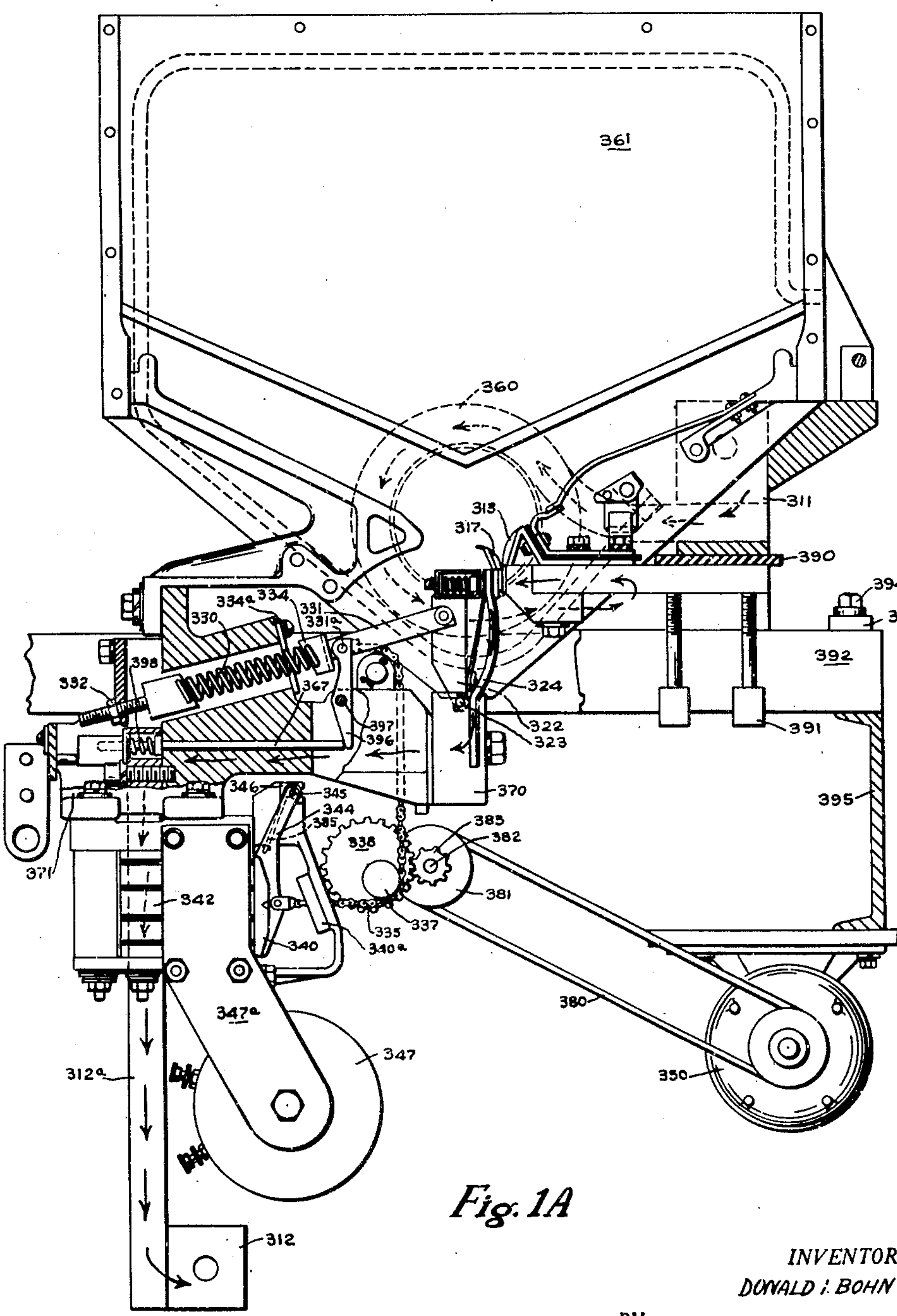

Fig. 1A

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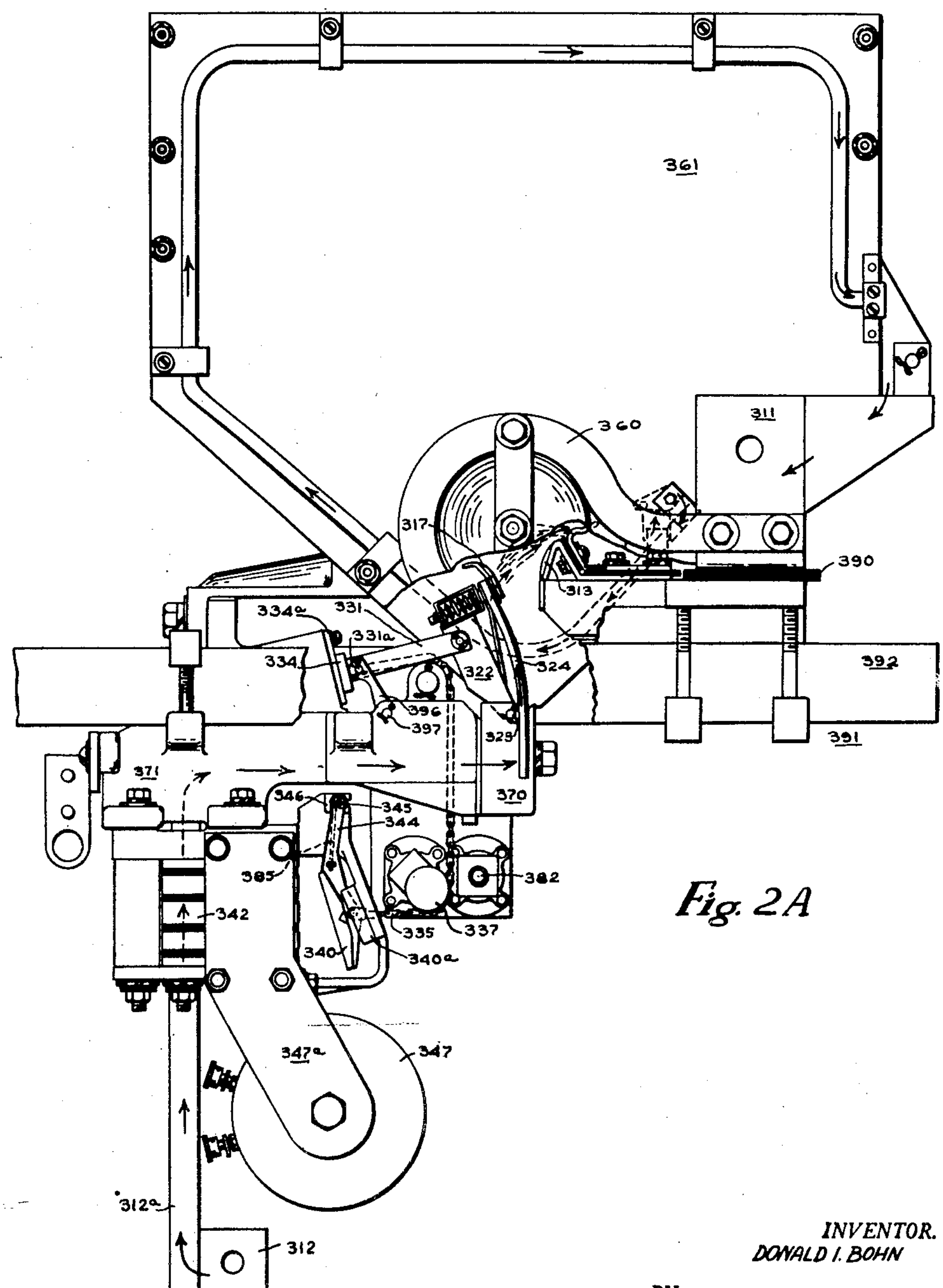

Fig. 2A

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CIRCUIT BREAKER

Original Filed July 28, 1942 5 Sheets-Sheet 4

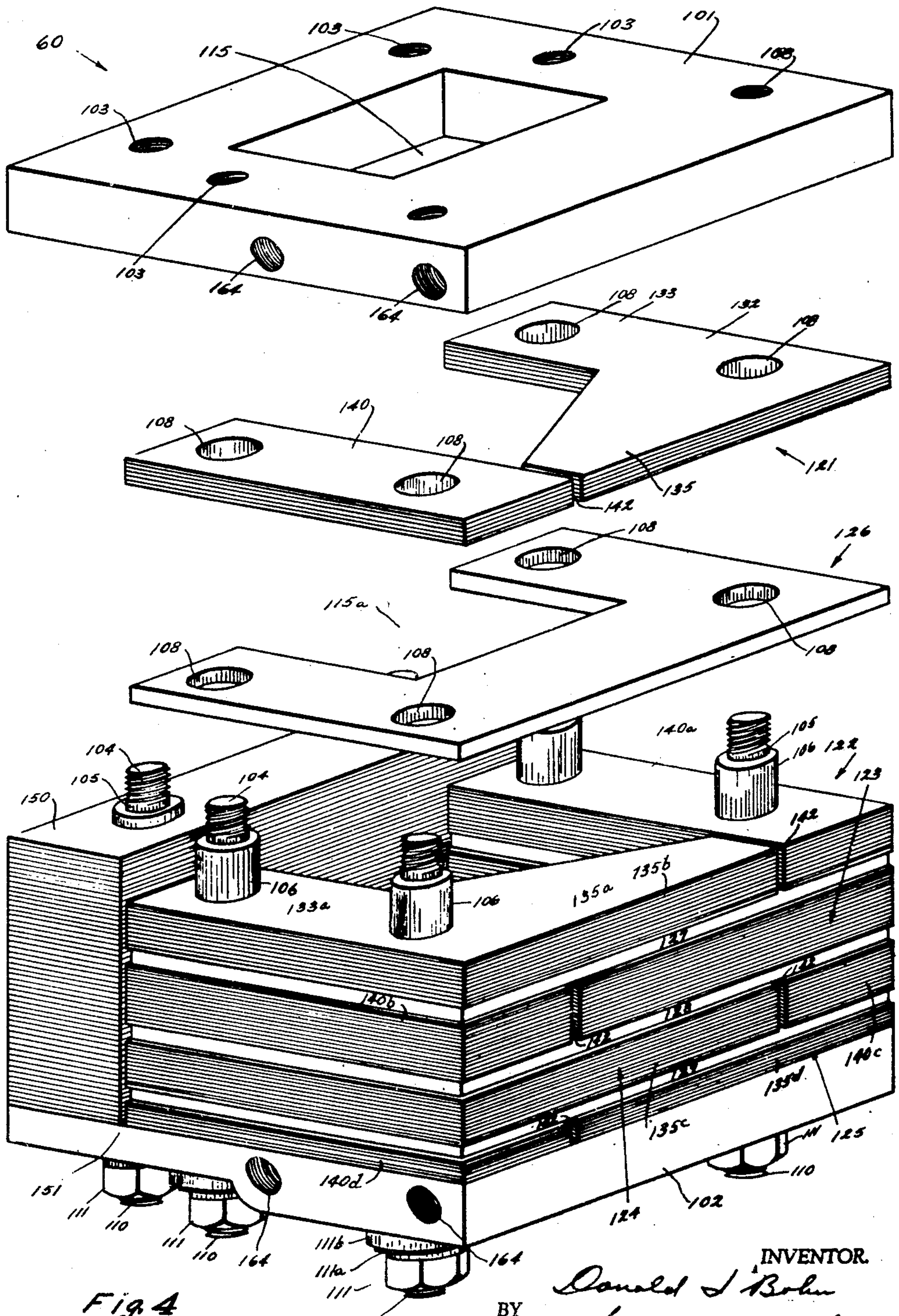

Fig. 4

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CIRCUIT BREAKER

Original Filed July 28, 1942 5 Sheets-Sheet 5

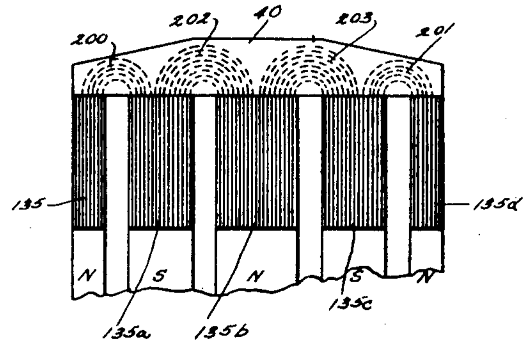

Fig. 5

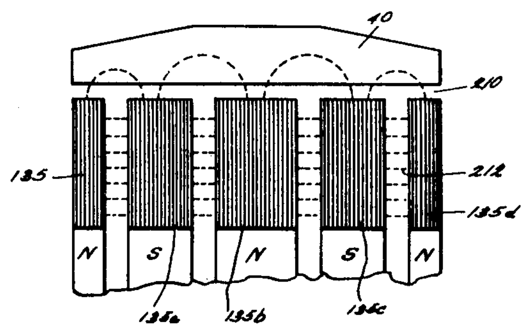

Fig. 6

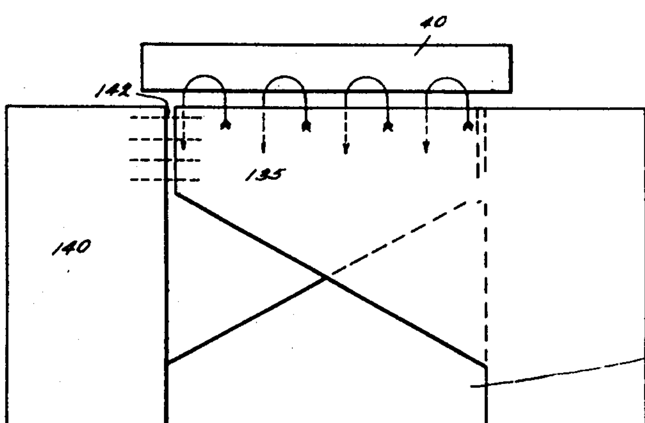

Fig. 7

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2,486,104

UNITED STATES PATENT OFFICE

2,486,104

CIRCUIT BREAKER

Donald I. Bohn, Pittsburgh, Pa., assignor to I-T-E Circuit Breaker Company, Philadelphia, Pa., a corporation of Pennsylvania

Original application July 28, 1942, Serial No. 452,613. Divided and this application March 1, 1944, Serial No. 524,540

8 Claims. (Cl. 200—89)

This application is a division of my Patent No. 2,412,247, issued December 10, 1946, and relates to circuit breaker apparatus and more particularly relates to a novel magnetic structure controlling the closing and tripping operation of a circuit breaker.

The circuit breaker of the present invention employs a magnet and armature design reducing the armature weight in a ratio of approximately 1:3, as contrasted with a conventional holding magnet.

As will be obvious, in order to secure the same effective armature area for a smaller weight of armature, I may decrease the radius and correspondingly increase the length of the armature. Thus, an armature having a radius of 1¼'' and a length of 2.94'' will weigh 1.582 pounds without mounting details. An armature whose radius is $\frac{13}{32}$'' and whose length is 6.45'' will have the same effective armature area but weigh only .55 pound—approximately one-third the weight of the first armature.

Quite obviously, however, an armature of such great length compared to its diameter would be entirely impractical from a mechanical and stiffness point of view.

In accordance with my invention, I carry out this principle of weight reduction which overcomes the mechanical defects noted above. In one form of my invention the armature weight is .55 pound and has an armature pull of 400 pounds.

I have discovered that I may materially reduce the mass of the armature and thereby increase the acceleration thereof by so arranging the magnetic structure of the holding magnet that there are, in effect, a plurality of individual magnets, each with its individual armature.

Inasmuch as the center of the armature which is mechanically connected to the movable contact of the circuit breaker assumes the greatest share of the carrying load in operating the movable contact and this load on the armature is gradually reduced as the edges of the armature are approached, I provide maximum thickness of metal at the center of the armature with a tapering armature construction toward the ends to a substantially reduced thickness at the ends.

This serves to prevent any deflection of the center of the armature which might tend to occur if the armature were of uniform cross-section; such deflection at the center should it occur would result in a reduction of the holding force on the armature and hence result in a rapid progressive release of the armature.

In order that the distribution of armature mass in this manner from maximum thickness at the center to minimum thickness at the ends may correspond to the flux distribution, the magnetic circuits are so arranged that a maximum number of lines of force exist at the center and the number of lines of force is reduced towards the edges of the armature.

My novel circuit breaker provides for tripping of the breaker on de-energization of the holding magnet armature and permits the armature of the magnet to be operated into engagement with the pole face of the magnet while the circuit breaker is still in disengaged position, the actual closing operations of the circuit breaker being performed by a separate power supply. This enables the use of a flexible connection from the armature to the movable circuit breaker contact, thus further reducing the mass and permitting a more rapid tripping operation.

Accordingly, an object of my invention is to provide a novel construction of a holding magnet in which tripping is effected by de-energization of the magnet armature.

Still a further object of my invention is to provide a novel circuit breaker structure in which a flexible connection extends from the armature to the movable circuit breaker contact.

There are other objects of my invention which together with the foregoing will appear in the detailed description which is to follow, in connection with the drawings, in which:

Figure 1 is a schematic view of my circuit breaker operating element showing the contacts closed.

Figure 1*a* is a view of a commercial embodiment of the structure schematically shown in Figure 1.

Figure 2 illustrates the trip position of the circuit breaker in Figure 1.

Figure 2*a* is a view of a commercial embodiment of the structure schematically shown in Figure 2.

Figure 3 is a view corresponding to that of Figure 1 showing the movement of the apparatus for normally opening the circuit breaker.

Figure 4 is an exploded view in perspective of the operating magnet of my circuit breaker.

Figures 5, 6 and 7 are additional diagrammatic views further illustrating the operation of the magnet.

Referring now to Figures 1, 2 and 3, I have here shown in schematic form the construction and operation of a circuit breaker utilizing my invention. The circuit breaker here shown includes circuit connecting members 11 and 12, which form the terminals of the circuit breaker and are arranged to be connected into the external circuit.

An L-shaped stationary contact member 13 having a contact surface 14 and a securing bracket 15, is mounted by means of the bolt 16 on the connecting bar 11. The stationary contact 13 may be engaged by the movable contact 17 which also is an L-shaped member having a contacting surface 18 and a mounting bracket 19. A bolt 20 passes through the mounting bracket 19 and secures the movable contact 17 to the upper portion of the movable contact carrying lever 22.

Lever 22 is pivoted for rotational movement at 23. A flexible laminated conductor 24 is secured in any suitable manner, as for instance, by the bolt 25 to the lower end of the lever 22, and at its opposite end is secured by the bolt 26 to the end of the connecting bar 12.

When, therefore, the circuit breaker contacts are closed, a circuit is completed from conductor 11 through the stationary contact 13 to the movable contact 17 through the movable contact carrying lever 22 and the flexible lead 24 to the connecting bar 12. A tension spring 30 is connected at one end to the ear 31 on the movable contact carrying lever 22, and at the other end, the spring 30 is connected to a lug 32 mounted on the frame of the mechanism. Tension spring 30 therefore biases the movable contact carrying lever 22 into counterclockwise rotation and hence biases this member to open circuit position.

When the circuit breaker is open as seen in Figures 2 and 3, then the movable contact lever 22 rotates counterclockwise against the stop 34, which limits further rotational movement thereof. The said stop is, of course, arranged in such position as to permit the movable contact to move a sufficient distance away from the stationary contact to ensure proper circuit interrupting capacity.

When closed, the contacts are normally maintained in engagement by means of the flexible member 35, which may take any desired form, such as a chain. The chain 35 is connected at one end to an ear 36 mounted on the contact lever 22 preferably approximately midway between the pivot point 23 and the free end which carries the movable contact 17. This chain passes over the roller 37 which is mounted on the operating crank 38. The other end of the chain is at 39 secured to the armature 40 which is normally held in engagement with the operating magnet 42.

The armature 40 is pivotally mounted on the lever 44 which is rotatably mounted on the pivot 45, which in turn is carried by lugs 46 associated with the frame of the magnet 42.

The magnet 42 is normally energized by a constant potential direct current coil 47 which provides adequate flux to maintain the armature 40 in contact with the pole pieces against the pull of the spring 30 transmitted by the chain or flexible member 35.

Current flowing through the series conductor 12 affects the flux between the magnet and the armature so that under certain conditions of direction and intensity of current flow, as hereinafter described, the flux through the armature is inadequate to counteract the effect of the spring 30, and the circuit breaker contact is pulled to open position.

The crank 38 may be operated for the purposes

hereinafter described to close or to open the circuit breaker independently of the magnet 42 and the armature 40.

A motor 50 is used to operate a multi-pole unit, driving, through an insulating shaft, the high speed shaft 51 of small speed reducers 52; one speed reducer being mounted on each pole. The low speed shaft 53 of each speed reducer carries the crank 38 and its roller 37.

If the motor 50 is run sufficiently to drive crank 38 through 360° and the armature 40 is sealed against the pole face of magnet 42, the effects of the chain 35 riding on the crank roller 37 is to cause the breaker to go through an open-close cycle, as shown in Figures 1 and 3.

A limit switch may be utilized for controlling the motor which, with suitable braking, ensures that the crank and roller will stop at the proper point in the operating cycle either for closing or opening.

In Figure 2, the circuit breaker contacts are shown in the open position, having opened automatically because the flux in the magnetic path of magnet 42 and the armature 40 was reduced beyond the critical value necessary to counterbalance the tripping force exerted by the spring 30.

Accordingly, the spring 30 has caused the lever 22 to rotate counterclockwise, thus pulling the chain 35 over the roller 37 and lifting the armature 40 away from its magnet 42.

Figure 3 shows the first necessary step for reclosing the circuit breaker after it has operated open to the position shown in Figure 2. With the breaker contacts disengaged and armature 40 in its uppermost position, the crank 38 is rotated by motor 50 through 180° so that the armature is permitted to fall by gravity against the pole face of magnet 42, and the flexible member 35 is shown completely slackened having no tension at this particular phase of the operation. The circuit breaker may now be reclosed by energizing the coil 47 to assure that there is adequate holding flux passing through the armature 40. The shaft 53 is then rotated by means of the motor preferably in a clockwise direction to rotate the crank 38 and the roller 37 so that flexible member 35 is drawn taut and then is effective to pull the contacts into engagement and maintain them in the position shown in Figure 1.

To open the circuit breaker without relying on the automatic circuit breaker opening means, the field coil 47 may be deenergized, which will result in the release of armature 40 and a consequent opening of the circuit breaker; or the motor 50 may be rotated so that shaft 53 is rotated through 180°, thus bringing the circuit breaker to the position shown in Figure 3. In each case, the circuit breaker may be opened.

In the foregoing, the principle of the formation of my circuit breaker has been set forth in its simplest form.

Either of the contacts 13 or 17 may obviously be resiliently mounted upon their respective supports.

The type of holding magnet shown in Figures 1, 2 and 3, is of a conventional "bucking bar" type well known in the art. The actuating mechanism of the circuit breaker may, of course, be effective with any of the well-known releasable holding means. The type of holding magnet which I prefer, however, to use in the circuit breaker of the present type, and which also has many additional functions and operations, is that shown in Figures 5 to 7 inclusive.

In Figures 1a and 2a I have shown a commercial circuit breaker structure which follows all of the principles heretofore described in connection with the schematic showings of Figures 1, 2 and 3. The circuit breaker shown in these figures includes the circuit connecting members 311 and 312 which form the terminals and are arranged to be connected into the external circuit.

During normal operation of the circuit breaker when the circuit breaker is closed, as seen in Figure 1a, current passes from the upper connected terminal 311 in the direction indicated by the arrows through the blow-out coil 360 of the arc chute 361 to the stationary contact structure 313.

Stationary contact structure 313 is engaged by the movable contact 317 which is mounted on the upper portion of the movable contact lever 322. Lever 322 is pivoted at 323 on the frame 370 of the circuit breaker.

A pigtail connection 324 is provided between the contact 317 and the conductive frame 370.

Current then flows to the front terminal assembly indicated generally at 371, whence it flows through the bucking bar 312a to the lower connecting terminal 312.

The blow-out coil 360 in the arc chute 361 may be of the form shown in Patent No. 2,405,454, issued August 6, 1946, to William M. Scott, Jr., or in Patent No. 2,381,637, dated July 31, 1945, to Donald I. Bohn, each of which is assigned to the assignee of the present application.

When the contacts 313 and 317 are closed, the circuit is then completed from the connector 311 through to the connector 312.

A tension spring 330 is connected at one end to the link 331 which, in turn, is connected to the movable contact lever 322—and at the other end, the said spring 330 is connected by means of the adjustable nut 332 to the frame of the mechanism. Tension spring 330, therefore, biases movable contact carrying lever 322 into counterclockwise rotation and thus biases this member to open circuit position.

The member 334 carried by the link 331 acts as a stop against the stationary cover plate 334a of the housing for the spring 330 when the circuit breaker is open, as seen in Figure 2a—thus limiting further rotational movement of the lever 322 in counterclockwise direction.

The stop members 334 and 334a are, of course, arranged in such positions as to permit movable contact 317 to move a sufficient distance away from the stationary contacts to ensure proper interrupting capacity.

When the contacts are closed, as shown in Figure 1a, they are maintained in engagement by means of the chain 335 which is connected at one end to the pin 331a of link 331 (and is, therefore, connected to the movable contact lever 322), and which is secured at its opposite end to the armature 340 which is normally held in engagement with the magnet 342.

Armature 340 is rigidly mounted on the lever 344 which is rotatably mounted on the pivot 345 which, in turn, is carried by the extension 346 associated with the frame of the magnet 342.

The magnet 342 is normally energized by a constant potential direct current coil 347 which provides through the pole pieces 347a adequate flux to maintain the armature 340 in contact with the pole pieces of the magnet 342 (in the manner hereinafter described) against the bias of the spring 330 transmitted through the chain 335.

The chain 335 passes over the roller 337 which is mounted on the operating gear 338.

Current flowing through the bucking bar 312a affects the flux between the magnet and the armature (as hereinafter described), so that under certain conditions of direction and intensity of flow, the flux through the armature is inadequate to counteract the effect of the spring 330, and the movable contact 317 is pulled to open position. This open position is shown in Figure 2a, where it will be seen that the stop members 334 and 334a of the contact lever have been engaged as the contacts open. It will also be seen that a suitable shock-absorbing stop 340a is provided for the armature 340.

The gear 338 may be operated to close or to open the circuit breaker independently of the magnet 342 and the armature 340.

A motor 350 is used to operate a multi-pole unit driving each of the units simultaneously. Motor 350 is connected by the belt 380 and pulley 381 to shaft 382 which is preferably an insulating shaft extending through the entire multi-pole unit to drive all of the elements simultaneously.

Pinion 383 on shaft 382 drives the gear wheel 338.

If the motor 350 is run sufficiently to drive the gear 338 through 360° and the armature 340 is held against the poles of the magnet 342, the effect of the chain 335 riding on the roller 337 is to cause the circuit breaker to go through an open-closed cycle as shown schematically in Figures 1 to 3.

In Figure 2a, the circuit breaker contacts are shown in the open position, having opened automatically because the flux in the magnetic path of magnet 342 and armature 340 was reduced beyond the critical value necessary to counterbalance the tripping force exerted by the spring 330. Thus, the spring 330 is causing the lever 322 to rotate counterclockwise, thus pulling the chain 335 over the roller 337 and lifting the armature 340 away from its magnet 342.

By now rotating the roller 337 through 180°, the chain 335 of Figure 2a will be slackened so that the coil spring 385 engaging the armature arm 344 will be free to drive the armature 340 toward the pole face of magnet 342.

Coil spring 385 is sufficiently light so that it will not interfere with the opening of the circuit breaker. Yet, when the chain 335 becomes slack by reason of this 180° rotation of the gear 338, the coil spring 385 will have sufficient force simply to re-set the armature 340.

Since current no longer flows through the bucking bar 312a by reason of the opening in the circuit breaker, the coil 347 will generate sufficient flux in the magnet 342 to hold the armature 340 and the magnet 342 together despite the tension on spring 330.

Now, therefore, when the gear 338 is rotated through another 180°, the roller 337 and all of the other elements of the circuit breaker will be brought back to the position shown in Figure 1a. This is so since one end of the chain 335 is effectively anchored by the holding of the armature 340 against the poles of magnet 342 and the other end is secured to the contact lever.

Thus, the circuit breaker may be opened in two ways: one, by rotating the gear 338 through 180° to slacken the chain 335; the other, by de-energizing magnet 347 which will reduce the flux sufficiently to cause a release of the armature 340. The circuit breaker will, of course, be tripped in accordance with the principles hereinbefore and hereinafter pointed out, where, in a reverse current flow, as indicated in Figure 2*a*, the flux generated by the current flowing in the bucking bar 312*a* will oppose the flux generated by the coil 347 and thus reduce the net flux through the magnet 342 and armature 340 sufficiently to permit the spring 330 to effect a separation of the magnet and armature.

The manner of the mounting of the circuit breaker here shown has not been described in detail since it corresponds exactly to the manner of mounting of the circuit breakers shown in Patent No. 2,393,687, dated January 29, 1946, to Otto Jensen and in Patent No. 2,405,454, dated August 6, 1946, to William M. Scott, Jr., which are assigned to the assignee of the present application. It is sufficient to say that a clamping plate 390 and clamping bars 391 secure the entire mechanism to parallel insulated cross bars 392 which are in turn secured by clamping plates 393 and bolts 394 to opposite longitudinal channels 395.

In the device here shown a simple indicating means is provided to show the condition of the circuit breaker. A lever 396 is pivotally mounted at 397 on the frame 370. One end of the lever is pivotally connected at 331*a* to the link 331. The other end of the lever bears against the indicating rod 367 which is biased inwardly by the compression spring 398.

When the circuit breaker is in the closed circuit position shown in Figure 1*a*, the lower end of the lever 396 bears against the rod 367 to force it outwardly to the dotted line position against spring 398 to indicate the closed circuit position.

When the circuit breaker is opened, the lever 396 rotates counterclockwise thus permitting the spring 398 to force the rod 367 to the right and draw the rod inwardly thereby indicating the open circuit condition.

It is obvious, of course, that the stationary contact structure 313 is insulated from the remainder of the circuit breaker as shown, since the remainder of the circuit breaker structure, including the main frame or housing 370, is conductively connected to the movable contact member 317.

Referring now to Figure 4, there is here shown in partially exploded form the holding magnet 60 which constitutes a primary element of my invention. The holding magnet, as may be seen in Figure 4, comprises a rectangular structure consisting of stacks of laminations which provide spaced and interleaved pole pieces of opposite polarity. This system provides a plurality of short flux paths (hereinafter described in connection with Figure 5) through the armature and results in an extremely quick acting release. The electrical and magnetic properties and the advantages in actual operation of my holding magnet will be more specifically set forth after the following description of the specific physical arrangement thereof.

The stacks of laminations are held together by a pair of non-magnetic frame plates 101 and 102. Plate 101 is provided with a plurality of tapped perforations 103, 103 to receive the ends 104, 104 of a plurality of studs 105. Studs 105 are insulated from the metallic laminations hereinafter set forth by the insulating bushings 106, 106. These studs 105 pass through corresponding openings 108, 108 in each of the metallic laminations as hereinafter set forth, and also pass through openings in the lower plate 102—all of the openings in the plates and in the laminations being in registry with each other. The lower end of the studs are also threaded, and the entire assembly is securely integrated as a single unit by means of the nuts 111 which are threaded onto the ends 110 of the studs 105, and held in place by the lock washers 111*a* and washers 111*b*. The washer 111*b* is of insulating material to ensure that the nuts 111 are appropriately insulated from the plate 102.

A central opening 115 is provided in each of the plates 101 and 102 and registers with corresponding openings in each of the laminations formed by the plurality of magnetic sheets, as hereinafter set forth, in order to form a central opening through the entire structure through which the conducting bar 12 passes.

In Figure 4, the plate 101 and one layer of laminations and its associated insulating spacing plate is shown lifted from the entire stack in order better to illustrate the complete unit.

In the construction shown in Figure 4, the holding magnet is provided with five layers of laminations 121 to 125. Each of these layers of laminations is separated from the adjacent layer by insulating plates 126 to 129 respectively.

Referring now to layer 121, this layer, as do each of the others, consists of two sets of laminations. One of the sets or stacks 132 comprises sheets which are L-shaped in formation with one limb 133 forming the sides of the structure and provided with openings 108, 108 to receive the studs 105. The other limb 135 forms a magnetic pole in the manner hereinafter described.

Layer 121 comprises, in the same plane with laminations 132, another stack or layer of laminations 140 which consists of a plurality of sheets of a simple rectangular form and which forms an element of the other side of the structure. The stack 140 is also provided with openings 108, 108 to receive the insulated bolts. An air gap 142 is provided between the limbs 135 forming a pole piece, and the end of the rectangular stack of laminations 140. The insulating plate 126 is placed immediately beneath the layer 121 and immediately above the layer 122 in surface to surface engagement on opposite sides with each of the layers.

While sheet 126 should preferably be an insulating non-metallic sheet, it is sufficient, however, for purposes of operation of the holding magnet that it merely be a non-magnetic member. The insulating sheet 126 is U-shaped in formation and is provided with the central opening 115*a* which registers substantially with the central opening 115 in each of the outer plates 102 and 101 to permit the conducting bar 12 to pass therethrough. Sheet 126 also has openings 108, 108 to permit the insulating bushings to pass therethrough.

The next group of laminations immediately beneath, that is, layer 122 has the same form as the laminations in layer 121, but the members are reversed with respect to each other. Thus, the stack 140*a* in layer 122 extends immediately beneath the limb 133 of stack 132 in layer 121; and limb 133*a* of stacks 132a in layer 122 extends immediately beneath the stack 140 in layer 121.

In layer 123, the positions of the stacks are again reversed so that the L-shaped stack extends beneath the L-shaped stack of layer 121, and the rectangular stack of layer 123 extends beneath the rectangular stack in layer 121.

In layer 124, the positions are again reversed so that the arrangement of the stack corresponds exactly to that of layer 122; and again in layer 125, the positions are reversed so that the arrangement of the stacks in the layer corresponds to the arrangement in stacks 123 and 121.

Thus, in each adjacent layer, an L-shaped stack is in alignment with a rectangular stack, and a rectangular stack on the opposite side is correspondingly in alignment with the adjacent L-shaped stack on either side of the layer.

Insulating spacing plates 127, 128 and 129, similar in every respect to spacing plate 126, are introduced between successive layers of laminated stacks so that each successive laminated layer 121–125 is magnetically isolated from the others.

The laminated stacks, as well understood, are formed of magnetic material so that appropriate magnetic fluxes may be created in accordance with the operating characteristics hereinafter set forth.

An air gap 142 is provided in each layer between the rectangular stacks and the adjacent limb 135 of the L-shaped stack in the same layer for purposes hereinafter described in connection with Figure 14.

The pole pieces are formed by the limbs 135, 135*a*, 135*b*, 135*c* and 135*d* in the stack. Adjacent poles in adjacent layers are of opposite polarity in accordance with the structures hereinafter described. Thus, should pole 135 be north, then pole 135*a* will be south, 135*b* north, 135*c* south, and 135*d* north. The poles of opposite polarity are interleaved as shown in Figure 4 so that they extend substantially between each other to provide proper terminals for the magnetic paths through the armature in the manner hereinafter described. The manner in which the poles become of opposite polarity should be obvious upon inspection of Figure 4. Thus pole face 135 extends from the right-hand end 132 of the structure, and current induced in the laminated stack will produce a magnetic flux of a specific direction therein.

In layer 122, the fluxes will be of the same direction, but, however, pole face 135*a* extends from the left-hand side of the stack, and hence this pole will be of a polarity opposite to that of pole 135. Similarly, pole 135*b* extends once more from the right-hand end of the stack and pole 135*c* from the left-hand end so that in each case the polarity will be opposite. The arrangement is followed throughout the stack so that adjacent interleaved poles are of opposite polarity.

In order to complete the magnetic circuit between the ends of the laminations remote from the pole pieces, a single stack of rectangular laminations 150 is provided. This stack of laminations is secured between the end frame members 101 and 102 in spaced relation to the ends of the other laminations so that an air gap 151 is provided between the ends of stacks 132 and 140 and the stacks 150. This is done in order to reduce the possibility of saturating the magnetic material during normal operation.

The stack 150 is maintained in position, as will be obvious in Figure 4, by the insulated studs 105 which pass through corresponding registering openings in the stacks and in the end frame members.

This flux in the schematic showing of Figure 5 will flow through pole 161 through one of the magnetic laminations 135 and then through the armature 40 to the adjacent opposite pole 135*a*, returing through pole piece 160. A parallel magnetic circuit is provided from pole piece 161 through laminations 135*b*, armature 40 to laminations 135*a*, returning through pole piece 160. The flux flowing in laminations 135*b* divides as shown in Figure 5, some flowing through the armature 40 to laminations 135*c* and pole piece 160.

The manner in which the flux flows from pole to pole through the armature in each case is shown in the schematic cross-sectional view of Figure 5.

Thus, the flux in the laminations is divided into a plurality of parallel flux paths through the armature, each of the paths including only its individual portion of the armature as distinguished from prior magnet structures in which all of the flux in the magnetic structure must flow through the entire armature. Accordingly, for the same armature mass, my present structure will conduct a considerably larger number of flux lines by reason of the number of multiple magnetic paths than is the case of the standard magnet in which all the flux flows through the entire structure in a single series path.

In Figure 5, I have shown a cross-section through the magnetic pole pieces and the armature along approximately the center line. Again, since the armature need only be of sufficient thickness and strength to carry the flux between adjacent pole pieces, and thus is, in effect, a plurality of small armatures bridging separate air gaps, the cross section of the armature may become so small in respect to the physical force existing that in an armature of uniform cross section, an effect may very well be created wherein the center of the armature may be deflected. That is, the point 39, at which the external force exerted by the flexible chain 35 is exerted, may be drawn away from the pole face owing to the relatively small cross section required for the armature. In such a case, the slight flexing of the armature, which permits the center area thereof to be drawn away, may thus decrease the magnetic flux therethrough at the center. This decrease in magnetic flux at the center will thus decrease the net counteracting force exerted by the magnetic structure to the pull at the point 39, thus permitting the pull to be exerted more strongly, thus making it possible for the center of the armature to be deflected even more, and thereby permitting a greater portion of the armature to be drawn away. This successive action, which may occur very quickly, will, owing to the flexing of the armature, permit the armature to be released.

Accordingly, the armature 40 is thickened at its center portion to provide a better path for the passage of magnetic fluxes thereat, and the center stack of laminations is thickened so that the center pole face 135*b* is much thicker than the other pole faces.

Similarly, the pole faces adjacent the center pole face, that is, pole faces 135*a* and 135*c*, while not as thick as pole face 135*b*, are much thicker than pole faces 135 and 135*d*.

Since the stacks of laminations toward the center of the magnetic structure have the greatest thickness, consequently, they also have the greatest pole area and provide the largest amount of flux flowing into the armature. The armature itself, since it is thickened at the center, also provides an appropriate path for this increased amount of flux. This flux is progressively decreased toward the center of the armature.

It thus becomes possible to provide an armature of a minimum weight with greater physical strength than in cases where an armature structure of uniform cross-section throughout is used.

Thus, in Figure 5, the poles 135, 135b and 135d are indicated as being north. Flux lines 200 flow from pole 135 into the intermediate pole 135a. Also, flux lines 201 flow from pole 135d into the intermediate pole 135c. Flux lines 202 and 203 flow from the central pole 135b into the intermediate poles 135a and 135c. In each case, the magnetic circuit is completed from pole to pole through the pole pieces 160 and 161 through the core 167'.

On the occurrence of reverse current conditions in the bus bar 12, the flux tending to hold armature 40 in place against the force of the counteracting spring is reduced so that the armature is permitted to move away from the magnetic structure. As armature 40 moves a slight distance away from the magnetic structure, as shown in Figure 6, thus creating the air gap 210, then, under normal or steady current conditions, the introduction of such an air gap will cause the building up of the leakage between the adjacent poles so that the flux passing into the armature is so rapidly reduced that the pull exerted by the magnetic structure becomes substantially zero at a very small air gap 210, and the armature may then be drawn away from the magnetic structure very quickly.

During practical operating conditions in some installations, a fault current may increase in value at an exceedingly high rate. There are installations in which the rate of rise in current may be increased at ten million amperes per second. Under such conditions, it is essential that the speed of movement of the armature and the rate of rise of the flux in the air gap be so arranged that there shall be no tendency for the armature to be drawn back against the pole piece and so prevent the opening of the circuit breaker.

While the condition shown in Figure 6 represents a leakage flux from one pole piece to an adjacent one, which will occur during normal operating conditions, high rate of rise may change this action. At a very high rate of current rise, the flux increases correspondingly. I have found that rapidly changing flux will flow normally parallel to the plane of the laminations, and that they are so guided by the outer laminations that the cross leakage is substantially zero. Any flow of this flux of rapidly changing value normal to the plane of the laminations would tend to create eddy currents which would tend to oppose the cross flow. As a result of this condition, the situation shown in Figure 13 would not exist during a fault involving a very high rate of rise in current, and for this reason, it is necessary to provide, as shown in Figure 7, a relatively narrow air gap between the ends of a pole 135 and the rectangular stack 140. This air gap will provide a leakage for the flux produced by a current changing any value of rate of rise so that the tendency to draw the armature back against the pole pieces is eliminated.

From the above, it will now be clear that the magnetic path for fluxes flowing through the pole piece 160 is distributed through the laminations 121 to 125. Because of the variation in the number of laminations in section 121 as compared to the next section 122 and 123, less lines of force

will flow in the laminations 121, a greater amount of flow in 122 and still a greater amount in 123. The lines of force flowing in laminations 135 of layer 121 will in turn divide themselves, a larger proportion of such fluxes flowing from the lamination 135 to lamination 135a through the portion of the armature bridging 135 and 135a as shown at 200 in Figure 5.

A smaller proportion of such fluxes flows from lamination 135 through the armature which bridges the gap 142 to the layer 140. This is due to the fact that the reluctance of the smaller path to the armature from layer 135 to 140 is greater than the reluctance of the much larger path provided by the armature from layer 135 to 135a.

Moreover, the lines of force flowing in the magnetic structure are greater than the lines of force which could be carried by the armature cross-section at this point which further determines the distribution of lines of force.

In general, the distribution of magnetic lines of force is as illustrated in Figure 5. A relatively small number of lines flows from lamination 135 to 135a through the armature of reduced cross-section. A much larger number of lines 202 flows through laminations 135a and 135b through the armature of greater cross-section at this point. Thus, the portion of the armature which is subjected to greatest load also has the greatest mass of material and carries the largest number of lines of force and the portion of the armature which carries the least load is of the least cross-section and carries the minimum number of lines of force.

This is better shown and more evident from an examination of Figure 5, which shows portions of the metal between the lines of force 202 and 203 which perform no useful function in carrying magnetic lines of force.

This same principle may be carried out in other portions of the armature, if desired.

With the previous breaker, the current reached a value under a certain set of test conditions of 30,000 or 35,000 amperes when arcing was initiated; whereas, with this higher speed breaker, arcing may be initiated at appreciably less than half this value. As a consequence, satisfactory speed of arc travel during the early formation of the arc with the prior arc extinguisher was unsatisfactory, resulting in distress and delayed current limitation.

While I have here described my invention in connection with preferred, successful embodiment thereof, many variations in the actual form of the interleaved pole pieces, and many variations in the form and construction of the armature and of the circuit breaker itself, as well as many variations in the "bucking bar" arrangement and in the exciting coil and other elements of my invention, will now be obvious to those skilled in the art. Accordingly, I prefer to be bound not by the specific disclosures herein, but only by the appended claims.

I claim:

1. In a circuit breaker for protecting an electric circuit having a fixed and a movable contact having a spring for normally biasing said movable contact to disengage said fixed contact, an electromagnet having an armature and connected to be responsive to current conditions in the electric circuit being protected, a flexible connection from said movable contact to said armature, a source of power interposed between said movable contact and said armature of said electromagnet for operating said movable contact while said

electromagnet is energized against the biasing action of said spring to effect engagement of said contacts and for maintaining said flexible connection taut, said source of power being operable to loosen said connection from said movable contact to said armature whereby said armature may be operated by said electromagnet to engaged position with the pole face thereof without operating said movable contact.

2. In a circuit breaker having a fixed and a movable contact, an electromagnet having an armature and connected to be responsive to current conditions in the electric circuit being protected, a flexible connection from said movable contact to said armature, means including a source of power interposed between said movable contact and said armature of said electromagnet for maintaining said flexible connection taut, said means being operable to loosen said connection from said movable contact to said armature, said armature being operable by said electromagnet, while said connection is loose, to engaged position with the pole face thereof without operating said movable contact, said power means being operable to bring said flexible member to a taut position for operating said movable contact to engaged position with the fixed contact after said armature is in operated position against its pole face.

3. In a circuit breaker having a fixed and a movable contact biased to disengaged position, an electromagnet having an armature and connected to be responsive to current conditions in the electric circuit being protected, a flexible connection from said movable contact to said armature, means including a source of power interposed between said movable contact and said armature of said electromagnet for maintaining said flexible connection taut, said armature on de-energization of said electromagnet being operated by said biased contact away from said electromagnet, said means being operable to loosen said connection from said movable contact to said armature whereby said armature may be operated by said electromagnet to engaged position with the pole face thereof without operating said movable contact, said electromagnet on de-energization operating to permit said movable contact to disengage its fixed contact while maintaining said flexible connection taut.

4. In a circuit breaker having a fixed and a movable contact, said movable contact being normally biased to disengaged condition, an electromagnet having an armature and connected to be responsive to current conditions in the electric circuit being protected, a flexible connection from said armature to said movable contact, means including a source of power interposed between said armature and said movable contact for maintaining said flexible connection taut, said movable contact being selectively responsive to said interposed means and said armature for operating said movable contact to disengaged position by the operation of said interposed means to a position at which said flexible connection is loose while said armature is maintained in energized condition and in response to de-energization operation of said armature while said interposed member maintains the taut condition of said flexible connection.

5. In a circuit breaker having a fixed and movable contact biased to disengaged position, an electromagnet having an armature and connected to be responsive to current conditions in the electric circuit being protected, a flexible connection from said movable contact to said armature, means interposed between said movable contact and said armature of said electromagnet for maintaining said flexible connection taut, said means being operable to loosen said connection from said movable contact to said armature to effect disengagement of said contacts, said armature being operable by said electromagnet to engaged position with the pole face thereof without operating said movable contact to engaged position and means for operating said interposed member to bring said flexible member to a taut position for operating said biased movable contact to engaged position with the fixed contact while said armature is in operated position against its pole face, said armature having a maximum cross-section at the center and a minimum cross-section at the ends, said flexible connection being connected to said armature at its center and at the point of maximum cross-sectional area thereof.

6. In a latch free circuit breaker having a movable contact element having a closed and an open position for controlling an electric circuit; an electromagnet having an armature and connected to be responsive to current conditions in the electric circuit being protected; a flexible connection from said armature to said movable contact element for maintaining said contact in its closed position when said magnet is energized; means connected to said contact element for moving it to its open position directly in response to the de-energization of said electromagnet in response to a change in the electric circuit conditions; means operating on said connection for freeing said armature from said contact element to permit said electromagnet to be re-energized to operate the armature to its original position while said contact element remains in its open position, and means interposed between said contact and said operating means for operating said contact element to its closed position and for restoring said armature control over said contact element in its closed position.

7. In a circuit breaker having a movable contact element having a closed and an open position; means for biasing said element to open position; an electromagnet having an armature and connected to be responsive to current conditions in the electric circuit being protected, a flexible connection from said contact element to the armature of said electromagnet for maintaining said contact in its closed position when said electromagnet is energized; said flexible connection being operated by said biased element on the de-energization of said electromagnet in response to circuit conditions for permitting operation of said contact element to its open position; means interposed between said contact element and armature, said means and said electromagnet being jointly operative to restore said contact element to its closed position against the action of said first mentioned means, said electromagnet remaining energized to maintain said contact element in its closed position.

8. In a circuit breaker having a movable contact element having a first and a second position; an electromagnet having an armature and connected to be responsive to current conditions in the electric circuit being protected, a flexible connection from said armature to said movable contact for maintaining said contact in its first position when said electromagnet is energized; means operative on the de-energization of said electromagnet in response to circuit conditions

for operating said contact element to its second position; means interposed between said first means and said armature, said second means and said electromagnet jointly operating said contact element to its first position against the action of said first mentioned means; said electromagnet remaining energized for maintaining said contact element in its first position.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
769,812	Baxter	Sept. 13, 1904
969,345	Culver	Sept. 6, 1910
1,075,421	Hopkins	Oct. 14, 191[illegible]
1,134,422	Stratton	Apr. 6, 1915
1,272,445	Holliday	July 16, 1918
1,670,088	Walle	May 15, 1928
1,808,778	Jones	June 9, 1931
1,816,789	Pailin	July 28, 1931
2,068,553	Linde	Jan. 19, 1937
2,112,054	Thumim	Mar. 22, 1938