Our invention relates to electric circuit breakers, and more particularly to electric circuit breakers of the "current-limiting" type.

Electric circuit breakers of the current-limiting type referred to include three different means for causing opening of the contacts. The first of these means is the manually-operable means (sometimes motor-operated, subject to the control of an operator). The second of these means may be called "conventional automatic" opening means that is, means for causing opening of the contacts in response to abnormal current conditions of medium and high value, such, for example as from 125% to 300-600% of the nominal or maximum continuous current rating of the breaker. The third opening means is the ultrahigh speed or "current-limiting" means which operates in response to short-circuit currents above the 300-600% nominal current range. In accordance with the prior art, the manual-operating means and the "conventional automatic" opening means have ordinarily utilized the same basic mechanism. It is not possible, however, to use this same mechanism for the performance of the "current-limiting" contact opening action, since this must take place at much higher speeds than the inertia of the manual operating mechanism will permit. A circuit breaker of the type described which has proved particularly effective in operation is disclosed, for example, in co-pending application S.N. 491,840 Heft, filed Sept. 30, 1965, now Patent No. 3,315,189 and assigned to the same assignee as the present invention.

In accordance with the aforementioned Heft application, a latch or link carried by the contact opening arm of the manually operable mechanism is releasably held or latched in a first position in which it connects the contact opening arm to the moved movable contact. A contact-opening force developed upon the occurrence of extremely high short-circuit current conditions, is utilized to rotate this link with respect to the contact arm to move it out of the latched position, following which it moves or "translates," in straight-line manner, to an open-circuit position. In effect, a force-defeatable or "break-away" connection is provided such that although the movable contacts are normally retained in closed circuit position by the manually operable mechanism with substantial contact pressure, nevertheless, if the force acting on the contacts in opening direction becomes excessive, the contact is, in effect, disconnected from the contact arm and permitted to move open without moving the relatively heavy parts of the operating mechanism, and therefore without being required to overcome the inertia of such parts.

In the construction disclosed in the aforementioned Heft application, certain manufacturing and assembly problems were presented, largely because of the fact that the construction requires a "double" latch construction, i.e., one involving two latch pieces straddling the controlled contact opening rod. In addition the over-all construction arrangement made it difficult to assure consistent operation after a large number of automatic opening operations.

It is an object of the present invention to provide a current-limiting circuit breaker mechanism of the type disclosed in the aforementioned Heft application which shall be easy to manufacture and to assemble. It is another object of the invention to provide a mechanism of the type described which shall be capable of a greater number of operations without inconsistency of action.

In the drawings,

FIGURE 1 is a side elevation view of an electric circuit breaker incorporating the invention, portions of the casing being broken away to disclose the interior parts; FIGURE 2 is a perspective view of some of the interior parts of the circuit breaker of FIGURE 1; FIGURE 3 is a semi-schematic illustration of the operating mechanism of the circuit breaker of FIGURE 1 the parts being shown in the position they occupy when the circuit breaker has been manually moved to the "off" position; FIGURE 4 is a semi-schematic illustration similar to FIGURE 3, the parts being shown in the position they occupy when the manually operable automatically-operable mechanism is in closed condition, but the contacts are opened by action of the high-speed opening means; FIGURE 5 is a semi-schematic illustration similar to FIGURES 3 and 4, the parts being shown in the position they occupy when the manually operable automatically-operable mechanism is in its "tripped" or automatically opened condition; FIGURE 6 is an enlarged detailed view of the contact operating rod of the circuit breaker of FIGURE 1; and FIGURE 7 is a fragmentary semi-schematic illustration of a portion of the high-speed opening means of the invention.

Referring to FIGURE 1, the invention shown as incorporated in a three-pole electric circuit breaker comprising an outer enclosing casing of insulating material having a base 10 and a cover 11. For purposes of illustration, the casing is broken away to show the internal construction of the center pole of the circuit breaker. A line terminal 13 is supported on the base 10 on a conductor strap 13 suitably fixed to the breaker base by suitable means, not shown. The terminal strap 13 is connected to a first stationary contact support and arc runner member 14 supporting a first stationary contact 15. A second stationary contact 16 is supported upon a similar corresponding contact support and arc runner member 17 supported in spaced relation to the member 14 by suitable means, not shown. The stationary contacts 15 and 16 are interconnected by a movable bridging contact member 18 having contacts 19 and 20 thereon respectively.

The contact support and arc runner member 17 has connected thereto one end terminal portion 21 of a solenoid winding 22, the other end 23 of which is electrically connected to a conductor strap 24. The conductor strap 24 is connected at its opposite end to a terminal member 25 of the trip unit assembly 26, by suitable means such, for example, as the screw 27. The terminal member 25 has one end of a generally inverted U-shaped heater strap 29 connected thereto by suitable means, such as by brazing, the other end of the heater 29 being connected to an output or load terminal member 30, having a load terminal connector 31 supported thereon. The parts and connections just described comprise the current path through the center pole of the circuit breaker. Similar parts comprising similar current paths, are provided in each of the outer two poles of the circuit breaker.

Manual and conventional automatic operating mechanism

As previously described, the circuit breaker of the present invention is adapted to perform the usual functions of automatic electric circuit breakers in permitting the manually controlled opening and closing of contacts and also in providing for the automatic opening of the contacts upon the occurrence of sustained minor excessive current conditions or "overloads," as well as for the automatic opening of the contacts upon the occurrence of excessive current conditions higher than the moderate
overload condition but less than a high short-circuit condition. For a 100-ampere breaker, for example, "overload" condition may be considered to be those in the range of 125 amperes to 600 amperes, while the "high overload-low short-circuit" excessive current conditions causing operation of the "conventional magnetic" means may be considered to be those lying in the range of 600 amperes to 3000 amperes, and high short-circuit current conditions may be considered as being those above 3000 amperes.

The manual and conventional automatic opening operating mechanism, which is positioned in the central pole chamber of the circuit breaker and serves to operate the movable contacts of all three poles by ganging means to be described, is indicated generally at 33 in FIGURE 1, and comprises frames 34 (only one shown). The side plates 34 serve to support a pivot pin 35 of a releasable member or cradle 36. The releasable member 36 is releasably held in the position shown in FIGURE 1 by a latch member 37 pivotally supported on a pivot pin 38 carried by a bracket 39 mounted on the trip unit casing 32A. A pair of upper toggle links 41 are positioned on opposite sides of the releasable member 36 and are connected thereto by a pin 41A. A pair of lower toggle links 42, only one shown, are connected to the upper links 41 by a pin 49 at one end, and by a pin 45A to a pair of movable contact actuator plates 45, which are pivotally supported with respect to the bearing 19 on a pivot shaft 45.

Referring to FIGURE 2, it will be observed that corresponding pairs of contact actuator plates 47, 47 and 48, 48 are also provided in each of the outer pole chambers for the purpose of operating the contact members of the outside poles. The outer contact actuator plates 47, 47 and 48, 48 are rigidly connected to the contact actuator plates 45, 45 by means of an insulating tie bar 44.

Referring to FIGURE 1, a pair of tension springs 50 connect the toggle knee pin 49 to a generally U-shaped manually operable member 51 having an insulating handle portion 52 projecting outwardly through an opening 53 in the top wall 11 of the casing. The springs 50 are connected to the manually operable member 51 by means of pin 51A.

**Manual operation**

In the position shown in FIGURE 1, the contact actuator plates 45 of the central pole, as well as the contact actuator plates 47 and 48 of the outer poles to which the plates 45 are connected by the rigid interconnecting members 44, are retained in "on" position, holding the movable contacts in closed condition by a linkage system to be described. In order to move the contacts and mechanism to "off" position, the operating handle 52 is moved through a path as shown in FIGURE 3 (on/off) to "off" position. This moves the line of action of the springs 50 to the left of the pivot pin 41A interconnecting the upper toggle links 41 with the releasable member 36. This reverses the bias of the springs 50 on the links 41, and causes the toggle linkage to buckle to the left and the paris to move to "off" position, as shown in FIGURE 3. It will be observed that in this position the contact actuator plates 45 have rotated counterclockwise about the pivot 46. Since the outer plates 47 and 48 are rigidly connected to the central plates 45, they also move to corresponding "open" position, moving their contacts likewise to open position. The circuit breaker is closed by reversing the movement of the operating handle 52, returning it to "on" position.

**Automatic opening of the manually operable mechanism**

In accordance with the invention, means is provided for causing the automatic opening of the manually operable operating mechanism 33 upon the occurrence of overload and low short-circuit currents. This means comprises an elongated bimetallic strip 54 for each of the poles of the circuit breaker (only one shown) rigidly mounted at one end of the heater member 29 and carrying an adjustable "calibrating" screw 55 at its free end. Each of the calibrating screws 55 of the bimetallic strips 54 is engaged with a trip bar 57 which is supported on a pivot pin 57 supported in the trip unit casing, and biased for counterclockwise rotation by a spring 59. The common trip bar 56 also includes a depending portion 60 at each pole location carrying a magnetic armature member 61 which is adapted to be attracted to a generally U-shaped magnetic field piece 62 which embraces a portion of the heater conductor 29. The depending portion 60 of the common trip bar 56 in the center pole also has a latch surface 63 which serves to latch or releasably restrain an intermediate latch member 64 which is biased by a coil-type spring 65 in counterclockwise direction. The intermediate latch member 64 includes a projection 64A which is disposed to strike a portion 37A of the latch member 37 when the intermediate latch member is released from the latch surface 63. This causes clockwise rotation of the latch member 37 and release of the end of the releasable member 36 from the latch member 37. Since the line of action of the tension springs 50 extends to the right of the pivot pin 49 when released of the releasable member 36, the springs 50 rotate the releasable member 36 in clockwise direction, causing the projecting portions 41B of the upper toggle links 41 to engage a stationary pin 34A carried by the frame members 34. Further rotation of the releasable member 36 causes clockwise movement of the upper toggle links 41 with respect to the releasable member 36, moving them to the final or "tripped" position shown in FIGURE 3. Since this action substantially shortens the distance between the pins 41A and 45A comprising the ends of the toggle links 41-42, the contact actuator plates 45 are rotated counterclockwise by this action as indicated in FIGURE 3. This action is translated into opening movement of the contact in a manner to be described.

Upon the occurrence of short-circuit current conditions below the level required to cause high-speed opening in the manner to be described, the magnetic field piece 62 becomes sufficiently energized to attract toward it the armature piece 61 carried by the trip bar extension 60. This causes rotation of the trip bar 56, and release of the intermediate latch member 64 with subsequent tripping action in the manner just described. Following tripping of the operation, whether due to action of the bimetallic strip 54 or of the magnetic field piece 62, the intermediate latch is reset by moving the manually operable handle member 52 back to "off" position. This causes the bent-over end portion 51A of the manually operable member 51 to engage a portion of the releasable member 36 and to rotate it in counterclockwise direction about its pivot 35 until the free end portion thereof strikes the intermediate latch member 64 rotating it clockwise about its pivotal support to latched position. A fuller description of the latch mechanism described may be found in Patent 3,205,325, Sept. 7, 1965, H. W. Archer et al., assigned to the same assignee as the present invention. The manually and automatically operated operating mechanism per se is described in greater detail in Patent 3,155,803, issued Nov. 3, 1964, to K. W. Klein et al., and assigned to the same assignee as the present invention.

**Current-limiting opening mechanism**

In accordance with the present invention, there is provided, in addition to the operating means for manually opening and closing the contacts and for automatically opening the contacts upon the occurrence of overload and low short-circuit current conditions, means for causing high-speed opening of the contacts at medium and high short-circuit current conditions, and for doing this automatically and independently of the described manual and conventional automatic opening mechanism.

For this purpose, a "high-speed solenoid" 22 is provided, including a magnetic plunger or armature 67.
rigidly connected to a contact operating rod 68. The contact operating rod 68 extends through a magnetic field piece 69 or stator which also functions as a guide bearing positioned within one end of the coil 22 and at its forward portion is connected to an operating rod 70 carrying the movable contact member 18. The assembly comprising the rod 70 and movable contact member 18 is movable with respect to the main rod portion 68, being biased to the right as viewed in FIGURE 1 and FIGURE 6 by a compression spring 68* contained within the tubular rod 68, see FIGURE 6. One end of the spring 68* engages the end of the rod 70, and the other end of the spring 68* carries the pin 70C carried by the rod 68*. A lost-motion connection is provided between the rod 68 and the rod 70 by means of the pin-and-slot arrangement comprising pin 70A carried by the rod 70 and slot 70B in the tube 68. Following engagement of the contacts 19 and 20 with the stationary contacts 15 and 16, continued travel of the rod or tube 68 compresses the spring 68* and moves the end of the slot 70B a short distance away from the pin 70A.

The rod 68 includes a separate end portion 68A to which it is connected by an adjustable coupling member 68B which serves in the manner of a turnbuckle to vary the over-all length of the rod assembly to permit adjustment of the contact pressure, etc. The end portion 68A is bifurcated and straddles a portion of a high-speed connecting link or latch member 73, to which it is connected by means of the pin 71 extending through an elongated hole or slot 74 in the latch 73 (see FIG. 1). A fixed pin 75 is also provided which is rigidly attached to the plates of the mechanism frame of the center pole. (While a single pin 75 is shown, we may use a pin-and-roller combination to reduce friction.) Corresponding fixed pins 75A are carried by frame members 76 for the outside poles, which are fixedly attached to the base 77 not shown. The plates 45 are provided with accurate slots 76A providing clearance for the pin 75. In addition to providing such clearance, the ends of the slots 76 co-operate with the pin 75 to provide a stop or limit for the movement of the plates 45 in both the contact open and contact closed position. A slot 77 is also provided in the latch 73 to permit limited movement of this part with respect to the pin 75. The latch 73 includes a depending angular portion 78 having a tension spring 79 connecting the remote end thereof with a spring anchor member 80. In addition, the latch 73 includes two shoulder portions 82 and 83 and a hook portion 84, for purposes of description. If it is desired suitable stop means may be used to limit the motion of the plates 45. In such a case, the pin 75 would be rigidly carried by either the plates 45 or the latch 73, the other of such members being provided with a suitable slot to permit the required lateral movement or "translation" of the latch 73 when rotated so as to disengage shoulder 82 from the roller 85.

The latch or link 73 is supported and guided for pivotal, sliding, or combined pivotal-sliding movement between the plates 45 by means of stepped insulating bushings of suitable material, preferably nylon, 85, and 86 (see FIGURES 1, 3, and 4).

In the normal condition of the circuit breaker, as shown, for example, in FIGURE 1, the latch 73 functions simply as a connection between the contact actuator plate assembly 45 and the contact rod assembly 68, by means of the pin 71 and roller 85. In other words, the plates 45, the contact arm 44, and the roller 85 comprise a driven member, and the roller 85 comprises a detent releasably engaged by the latch member 73 whereby the latch 73 forms an operative connection between the aforementioned driving and driven members. Thus, in FIGURE 1, the operating springs 50 and toggle links 41, 42, and contact arm 44 cause the roller 85 to rotate a clockwise direction about their pivot 46. A steel roller 85b is carried by a pin 85A fixedly carried by the contact actuator plates 45. A pair of nylon bushings 85a also carried by the pin 85A help to guide the latch 73 in its movements.

In the normal condition as shown in FIGURE 1, the latch 73 is biased to the tension spring 79 clockwise about the pin 75, retaining the shoulder 82 in engagement with the steel roller 85B. FIGURE 5 shows the movement of the contact actuator plates 45, from the position shown in FIG. 3 to the position shown in FIG. 1 therefore carries with it the latch 73.

When the operating handle is moved to "off" or tripped position, the contact actuator plates 45 are rotated counterclockwise about the pin 75 against the tension of the spring 79, moving the shoulder 82 down below the latch roller 85B. When this rotation has occurred sufficiently to permit the shoulder 82 to clear the roller 85, the entire latch 73 translates or slides to the left as viewed, under both the influence of the spring 79 and the force of the solenoid 22. The parts then assume the relative positions as shown in FIGURE 4, with the latch roller 85B in engagement with the second shoulder 83.

It will be observed that the contact actuator plates 45 have not moved from their normal "on" position as shown in FIGURE 1. It will be recalled that this position is determined by the action of the pin 75 in the end of the slot 76 limiting clockwise motion of the actuator plates 45.

Tripping of conventional mechanism and resetting of high-speed links

Although the high-speed tripping action caused by the solenoid 22 takes place independently of the main operating mechanism, and before movement of the main operating mechanism toward tripped condition, the current levels required for actuation of the solenoid 22 are above the current levels required for actuation of the magnetic tripping means 62-61. Accordingly, substantially simultaneously with the movement of the plunger 67, the armature 61 is attracted to the field piece 62, causing release of the intermediate latch member 64. This in turn causes release of the main latch 37 and tripping of the main mechanism in the manner previously described. Because of the number of different parts involved and their mass, as well as the "chain reaction" sequence of movements required, tripping of the conventional or manually operable mechanism is not completed until after the high speed opening of the contacts has already taken place.

When tripping of manually operable mechanism does occur, however, the mechanism parts move to the tripped condition as indicated in FIGURE 5. It will be observed that as the conventional mechanism moves to its tripped position, the contact actuator member 45 moves counterclockwise to its fully opened position (compare the position of this part in FIGURE 1 to the same position in FIGURE 3, for example). As the contact actuator plates 45 are rotated counterclockwise as viewed, and once again gets behind the shoulder 82 "resetting" that latch 73. Note that the latch 73 is prevented from moving further to the left by the engagement of the end of slot 77 with pin 70A, so also that the latch 73 is biased clockwise at all times by spring 79.

The arrangement by which the armature 67 is directly connected, by a pin 70A, to the movable contact member
70. has the result that the movable contact member moves toward open position as soon as the armature moves. Thus there is no time lag after the armature 67 begins to move before the movable contacts begin to move. The aspects of the movable contact assembly by which this is made possible are the invention of E. B. Hefr and R. W. Laubenbergw and are covered in co-
ponding application Ser. No. 507,118 filed Nov. 25, 1966 and assigned to the same assignee as the present inven-
tion.

It will be observed, that the fixed pin 75 serves several functions. First, it serves as a pivot support for the link 73 in the normal latched condition of the link 73, when the armature spring 79 is pulling on the extension 78. This maintains the opposite end of the link 73 in engagement with the roller 85B and maintains the roller 85B behind the shoulder 82. Secondly it serves, in combination with the grooved rollers or bushings 85 and 86, to slidably guide the link 73 during its translating movement to the left during high-speed tripping. Thirdly, it serves as a stop to limit movement of the contact actuator plate 45 in both the closed and open directions, by engagement with corresponding ends of the slot 76. Finally, it serves to restrain movement of the high-speed link 73 to the left while resetting is occurring, in the manner just described.

By reason of the particular novel configuration of the latch 73, it will be observed that the surfaces of the high-
speed link 73 which are critical, that is, the surface of the shoulders 82 and 83, are readily accessible for ma-
ching and polishing to provide the required accuracy. This would not be the case if these surfaces were formed, for example, as portions of one or more closed slots.

The basic relation of the forces acting on the latch 73 is shown in FIGURE 7. As indicated, a component of the force originating in main mechanism springs 50 is exerted by the roller 85B on the latch member as force F-1. The greater part of this force is transmitted by the latch member 73 to the pin 71 and the contact rod 68 as contact closing force F-1. An equal and opposite force F-2 is, of course, exerted by the pin 71 on the latch 73.

In addition, the force F-3 of the solenoid 22 is always acting in contact opening direction on rod 68. Normally this force is insignificant. On high short-circuit condi-
tions, however, this force becomes substantial, and, adding to the recession force F-2, produces a torque tending to rotate the latch 73 counterclockwise about the pin 75 which is then great enough to exceed the clockwise torque constantly exerted by the force F-4 of spring 79 on latch 73. As a result, the latch rotates counterclock-
wise, moving the shoulder 82 below the roller 85B, permitting lateral rotation of the latch 73 to the left, opening the contacts. This movement is also assisted by the spring 79, cooperating with the solenoid 22 and with "blow-off" forces between the contacts.

While the invention has been disclosed in only one particular embodiment, it will be readily apparent that many modifications thereof may readily be made. It is there-
fore intended by the appended claims, to cover all such modifications as fall within the true spirit and scope of the invention.

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

1. A current-limiting electric circuit breaker comprising:

(a) a support;
(b) at least one pair of relatively movable contacts supported on said support;
(c) contact operating means supported on said support;
(d) connecting means connecting said contact operat-
ing means to said relatively movable contacts for operating said contacts between open and closed cir-
cuit positions;
(e) said connecting means comprising a driving member operably connected to said contact operating means and a driven member operably connected to said relatively movable contacts;
(f) means releasably interconnecting said driving and driven members comprising detent means carried by one of said driving and driven members and latching means connected to the other of said driving and driven members, said latching means having a portion engaging said detent means when said latching means is in a predetermined normal position;
(g) a pivot pin supporting said latching means for pivotal movement away from said normal position upon the exertion of predetermined force exerted on said driven member in contact-opening direction said pivot pin being fixed with respect to both said driving and driven members, and
(h) current responsive means for exerting said predeter-
determined force on said driven member in contact opening direction upon the occurrence of predetermined current conditions through said contacts, said latching means moving out of engagement with said detent means upon the occurrence of said predetermined force and permitting movement of said driven member in contact opening direction substantially in-
dependently of said contact operating means;

2. A current-limiting electric circuit breaker as set forth in claim 1 wherein said driving member includes a pair of spaced abutments, said abutments engaging said fixed pivot pin and limiting travel of said driving member in contact opening and closing direction respectively.

3. A current-limiting electric circuit breaker as set forth in claim 1 wherein said detent means comprises a roller carried by said driving member and said latching means comprises a latch member having an elongated slot therein, said pivot pin extending through said slot and cooperating with the ends of said slot to limit movement of said latch member with respect to said driving member also including an abutment engaging said roller, and spring means normally biasing said latch member for pivotal movement about said pivot pin to maintain said abutment in engagement with said roller.

4. A current-limiting circuit breaker comprising:

(a) a support;
(b) at least one pair of relatively movable contacts supported on said support;
(c) contact operating means supported on said support;
(d) connecting means connecting said contact operat-
ing means to said relatively movable contacts for operating said contacts between open and closed cir-
cuit positions;
(e) said connecting means comprising a driving member operably connected to said contact operating means and a driven member operably connected to said relatively movable contacts;
(f) means releasably interconnecting said driving and driven members comprising detent means carried by one of said driving and driven members and latching means connected to the other of said driving and driven members, said latching means having a portion engaging said detent means when said latching means is in a predetermined normal position;
(g) a pivot pin supporting said latching means for pivotal movement away from said normal position upon the exertion of predetermined force exerted on said driven member in contact-opening direction;
(h) current-responsive means for exerting said predeter-
determined force on said driven member in contact opening direction upon the occurrence of predetermined current conditions through said contacts, said latching means moving out of engagement with said detent means upon the occurrence of said predetermined force and permitting movement of said driven member in contact opening direction substantially in-
dependently of said contact operating means;
(i) said contact operating means comprising a member movable reciprocally between open and closed circuit positions;
(j) said latching means comprising a single latch mem-
ber having a slot therein through which said pivot pin extends;

(k) said detent means comprising a roller carried by one of said latch member and said driving member and a cooperating first abutment carried the other of said latch means and said driving member, and

(l) means pivotally connecting said contact operating member and said latching member.

5. A current-limiting circuit breaker as set forth in claim 4 wherein said one of said latch member and said driving member also includes a second abutment spaced from said first abutment and engageable by said roller upon movement of said driving member from said closed toward said open position.

6. A current-limiting circuit breaker as set forth in claim 1 wherein said contact operating means comprises means for manually operating said contact operating means for operating said contacts between open and closed circuit positions and second current responsive means for automatically moving said contacts from said closed to said open position upon the occurrence of predetermined second current conditions.

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