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Bogert

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[54] ELECTRIC CIRCUIT BREAKER WITH MEANS FOR PROMOTING CURRENT TRANSFER TO ARCING CONTACTS

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[52] **U.S. Cl.** ....**200/146 R**
[51] **Int. Cl.** **H01h 33/12**
[58] **Field of Search** ....200/146 R

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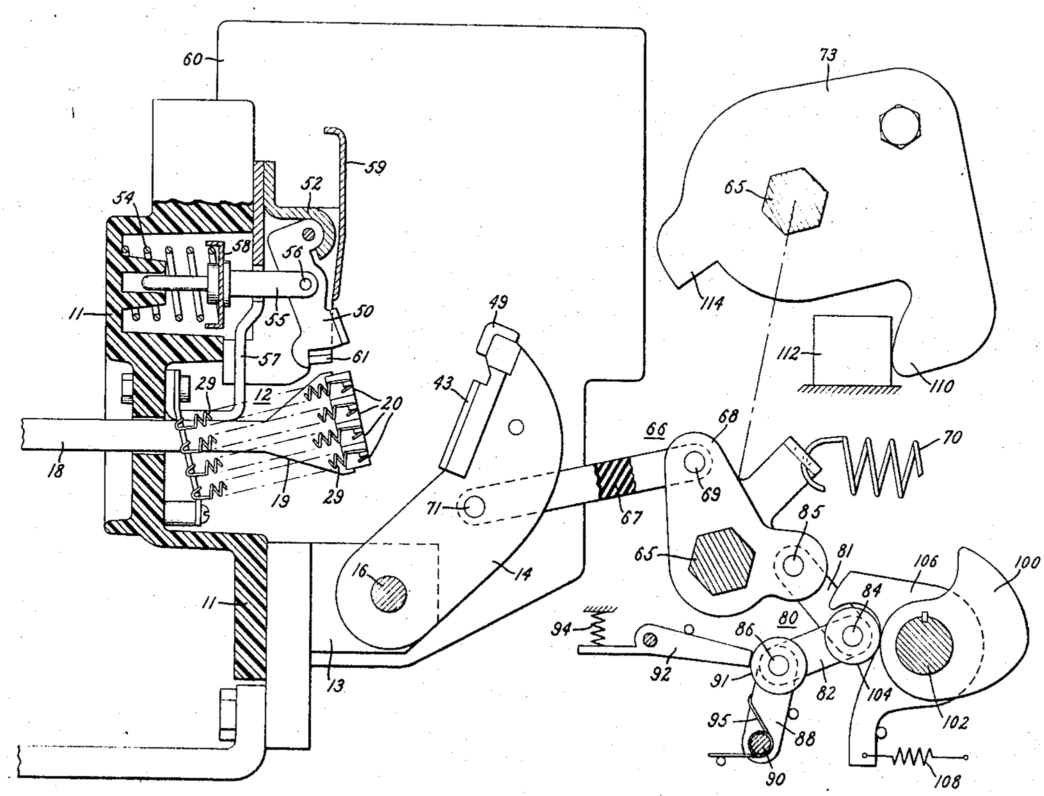
[57] **ABSTRACT**

A polyphase electric circuit breaker in which opening acceleration at the arcing contacts is severely limited until the main contacts part. For imposing this limitation on opening acceleration during the early part of an opening operation, a large flywheel mass is attached to the cross shaft that interconnects the pole units of the circuit breaker, and toggles interconnecting the cross shaft and the contacts are maintained in a zone near dead center until the main contacts part.

4 Claims, 4 Drawing Figures



Patented April 24, 1973 **3,729,606**

3 Sheets-Sheet 1

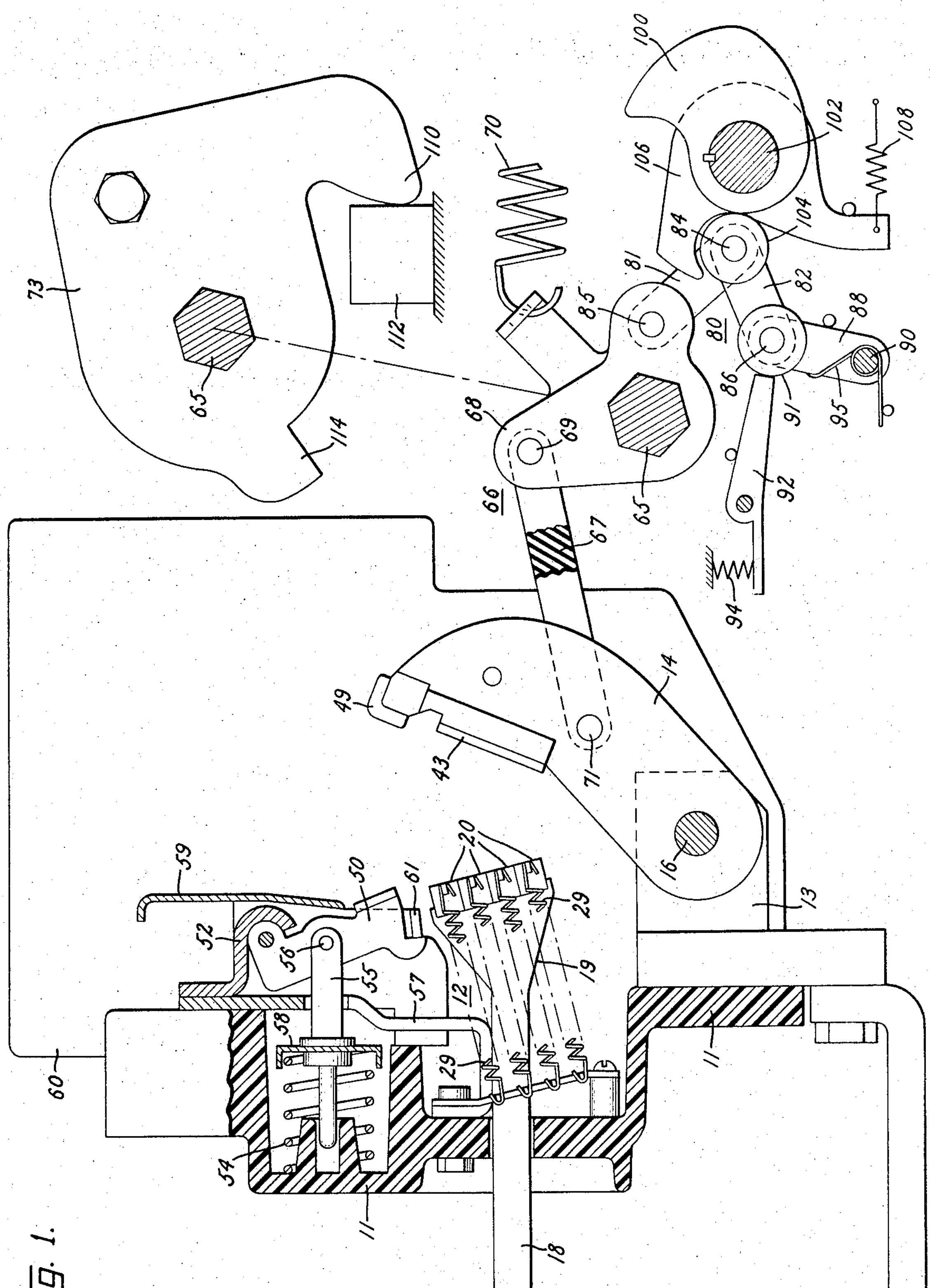


Fig. 1.

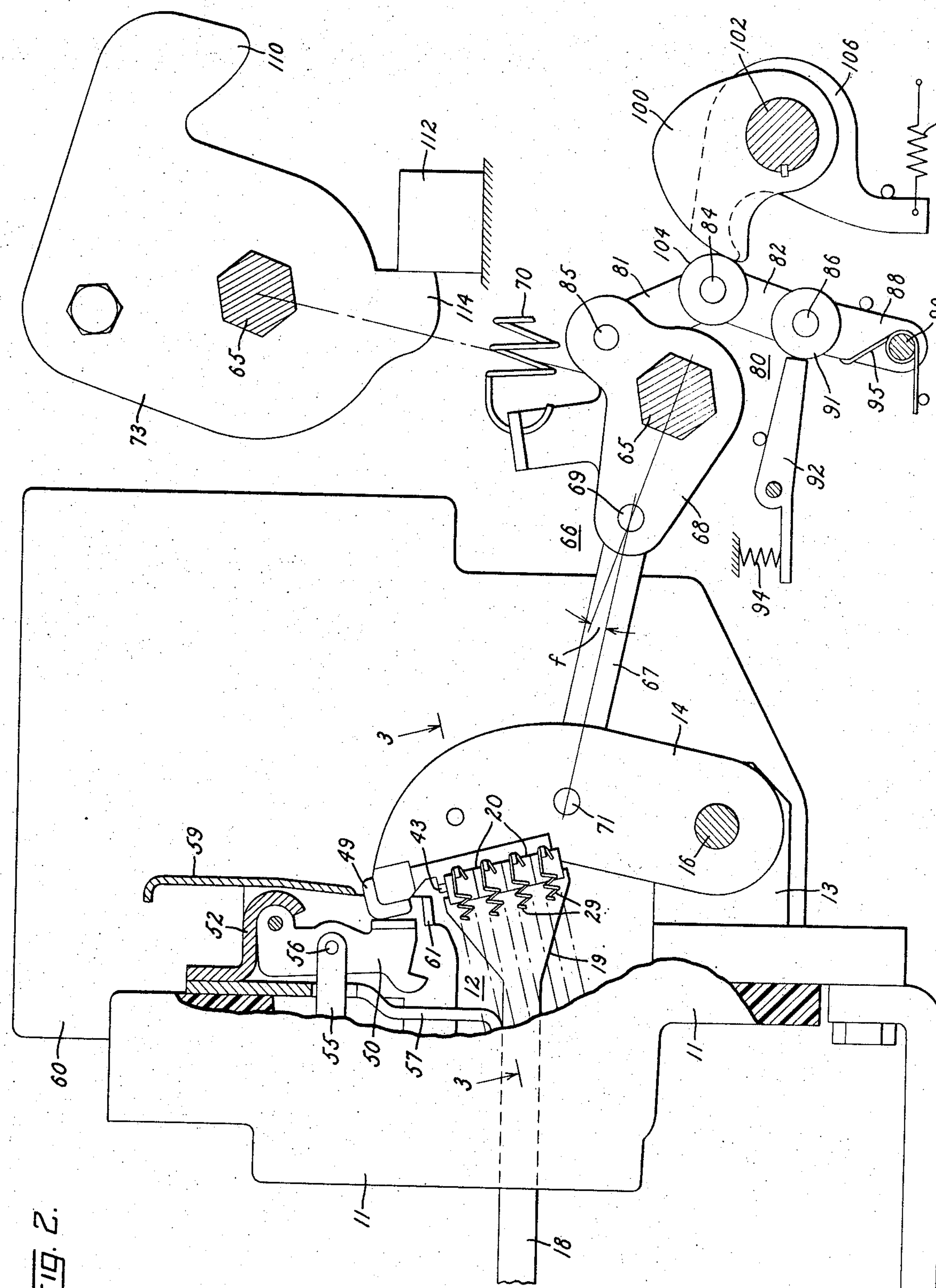

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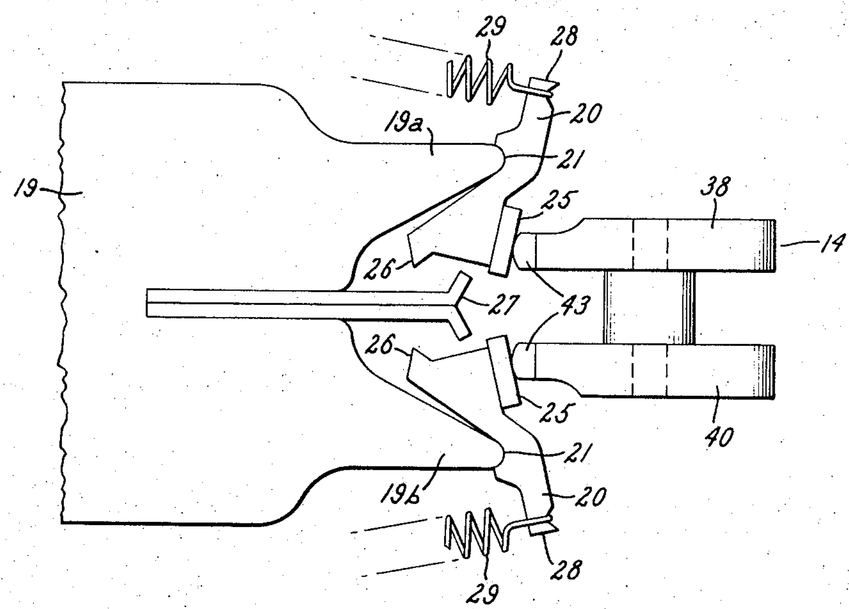
Fig. 2.

Fig. 3.



29
28
20
19a
21
19
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38
14
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27
43
26
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19b
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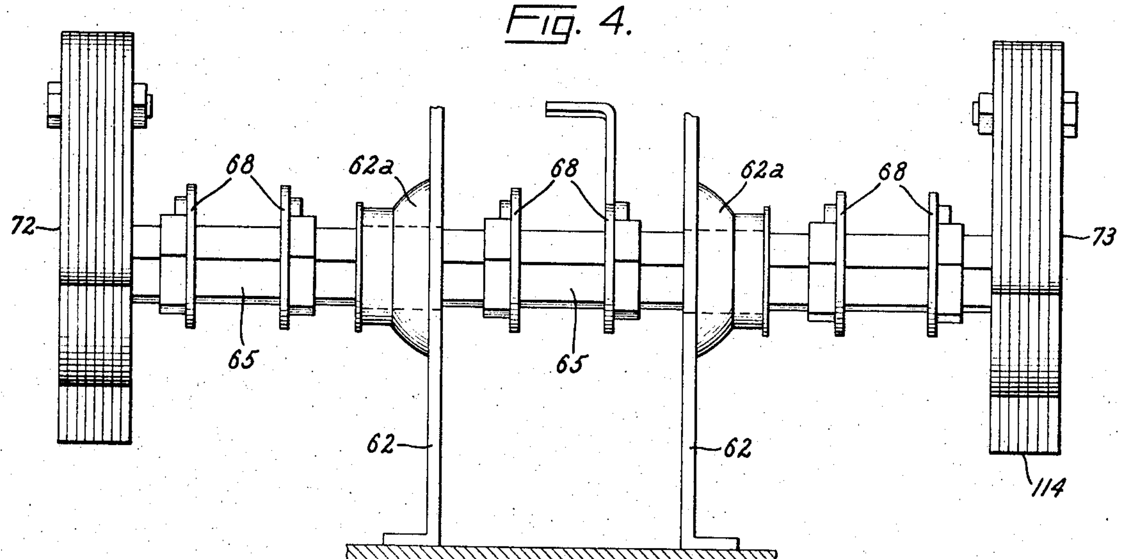
29

Fig. 4.



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62a
68
62a
68
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73
65
65
62
62
114

ELECTRIC CIRCUIT BREAKER WITH MEANS FOR PROMOTING CURRENT TRANSFER TO ARCING CONTACTS

BACKGROUND

This invention relates to an electric circuit breaker of the type that comprises main contacts that normally carry the principal current passing through the breaker and arcing contacts, to which this current is transferred during the early stages of an interrupting operation.

It is highly desirable in this type of circuit breaker to completely transfer the current off of the main contacts immediately after the main contacts separate during the interrupting operation. Otherwise, a persistent arc will be established at the main contacts upon their separation, and this arc can damage the main contacts, particularly if it is a high-power arc. In extreme cases of poor current transfer, the arc will persist indefinitely at the main contacts, failing to transfer into the usual arc chute and causing a complete failure to interrupt.

A factor that can interfere with the desired current transfer is the tendency of the arcing contacts to magnetically pop apart prior to complete transfer of current off the main contacts. This contact-popping action results from magnetic repulsion forces developed by current flowing through the arcing contacts while the main contacts are still carrying some current. These repulsion forces, if high enough, can force the arcing contacts apart, drawing an arc between them that develops an arc voltage tending to discourage the desired current-transfer from the main contacts to the arcing contacts. To resist such contact-popping, the arcing contacts can be provided with a heavy wipe spring biasing them together in opposition to the contact-popping force; but this approach has certain serious limitations, one of which is that the heavy wipe spring unduly increases the forces needed for completely closing the circuit breaker during a closing operation.

SUMMARY

An object of my invention is to promote complete current transfer from the main contacts to the arcing contacts by means which resists popping apart of the arcing contacts without necessitating an unduly heavy wipe spring for the arcing contacts.

Another object is to limit the loss of hold-closed force at the arcing contacts due to opening acceleration in the early stages of an opening operation without substantially reducing the speed at which the arcing contacts part later in the opening operation.

Another object is to provide means which severely retards opening acceleration at the arcing contacts until the point of main contact separation but which imposes much less retardation at the time the arcing contacts part and during subsequent portions of the opening operation.

In carrying out my invention in one form, I provide a polyphase electric circuit breaker comprising three pole-units, each comprising separable main contacts, separable arcing contacts, and a movable blade on which its movable main contact and its movable arcing contact are mounted. For coupling the blades of the pole-units together, a cross shaft mounted for angular motion is provided. Three toggles respectively connected between the cross shaft and the blades of the three pole-units are provided, each toggle comprising a pair of pivotally-interconnected links, one of which is pivotally connected to its associated blade and the other of which is coupled to the cross shaft for angular motion therewith.

Each of the toggles occupies when the circuit breaker is open a first position wherein said toggle links are displaced from dead center by a relatively large angular distance and occupy when the circuit breaker is closed a second position wherein the toggle links are disposed near dead center of said toggle. Each of the toggles is movable from said first to said second position during a closing operation and from said second to said first position during an opening operation. Each of the toggles is within 25° of dead center at the instant its main contacts part during an opening operation. A massive fly wheel coupled to said cross shaft for angular motion therewith is provided. The cross shaft and the fly wheel have a combined inertia that is at least 10 times as large as the total inertia of all of the generally stationary arcing contacts of the three pole units. The fly wheel coacting with the toggles has the effect of severely limiting the velocity and acceleration of the blades during the first stages of the opening operation, i.e., until the main contacts part, but of imposing relatively little retarding effect during the later stages of the opening operation.

BRIEF DESCRIPTION OF DRAWINGS

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

FIG. 1 is a schematic view of a preferred form of the circuit breaker in its open position.

FIG. 2 is a schematic view of the circuit breaker in its closed position.

FIG. 3 is a sectional view taken along the line **3—3** of FIG. 2.

FIG. 4 is a side elevational view of the cross shaft **65** which interconnects the pole units of the circuit breaker.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT MAIN CONTACTS

Referring now to FIG. 1, the illustrated circuit breaker comprises a base **11**, relatively stationary contact structure **12** mounted on the base, and an electroconductive bracket **13** mounted on the base in spaced relation to the stationary contact structure. A movable contact blade **14** is supported by bracket **13** for pivotal movement about an axis **16**. When movable blade **14** is pivoted counterclockwise from its open position of FIG. 1 into its closed position of FIG. 2, its upper portion is moved into circuit-making engagement with stationary contact structure **12**, as will soon be described in greater detail. After the contacts have been thus engaged, pivotal motion in the opposite direction will separate the movable blade **14** from stationary contact structure **12** to interrupt the circuit. Components **12**, **13** and **14** constitute the contact structure of one pole unit of a circuit breaker. As will soon be described, other similar pole units are mounted for gang operation on base **11** adjacent the illustrated pole unit.

Stationary contact structure 12 comprises a horizontally-extending conductive stud 18 projecting through base 12 and suitably secured thereto. At its right hand end, stud 18 has a portion 19, best seen in FIGS. 1 and 3, which at its forward end is divided into a pair of spaced lugs 19*a* and 19*b*. Pivotally supported on the outer end of each of these lugs is a contact finger 20. The outer end of each lug has a generally cylindrical bearing surface 21 which provides a fulcrum for the contact finger 20 pivotally supported thereon, and the pivotal connection between each finger and lug forms a current-carrying joint.

As can be seen in FIGS. 1 and 3, the contact fingers are arranged in pairs, and all are electrically interconnected by virtue of the lug portion 19 that supports them. The fingers of these pairs are respectively supported on opposite bearing surfaces in opposed relationship to each other, with the opposed fingers of each pair being movable in a common horizontal plane. The opposing or inner ends of the contact fingers 20 of each pair move in separate relatively-short arcuate paths. These ends are respectively provided with generally flat butt contact surfaces 25 extending generally vertically.

The inner end of each contact finger 20 has an extension 26 disposed to engage a common stop 27, as seen in FIG. 3, for determining the limit of the arcuate movement of the contact surface in one direction. The outer end 28 of each contact finger has a tension spring 29 connected thereto for establishing a biasing torque on the contact finger that tends to move contact surface 25 along an arcuate path in a forward direction away from base 11. As seen in FIG. 3, such movement of the finger will be limited by stop 27. This arrangement permits relatively limited deflection, or yielding, of each contact finger 20 in a rearward direction during a closing operation.

As shown in FIG. 3, the movable blade structure 14 comprises a pair of electrically parallel arms 38 and 40 mechanically tied together and respectively providing butt contacts 43. During circuit-closing movement, arms 38 and 40 and their respective butt contacts 43 move in vertically spaced parallel planes disposed approximately perpendicular to the planes in which the fingers 20 travel. When the surfaces of butt contacts 43 on the moving arms engage the butt contact surfaces 25 on fingers 20 at the end of a circuit-closing operation, each contact figure is pivoted on its fulcrum 21 against the biasing torque of spring 29. In this manner, the usual contact-wiping action is established between the mating contacts 20 and 43.

During an opening operation when blade 14 is pivoted clockwise about axis 16 in FIG. 2, the fingers 20 are forced by springs 29 to follow blade 14 until the fingers engage stop 27 (FIG. 3). When this engagement occurs, fingers 20 no longer follow blade 14, and subsequent blade movement in a clockwise opening direction separates movable contacts 43 from the finger contacts 20.

ARCING CONTACTS

For bearing the arcing duty that is imposed by an interrupting operation, two sets of arcing contacts 49 and 50 are provided for each pole unit. The arcing contacts 49 can be thought of as movable arcing contacts carried by conductive blade 14. The other arcing contacts 50 can be thought of as relatively stationary arcing contacts forming a part of the stationary contact assembly 12.

Each of the relatively stationary contacts 50 is in the form of a conductive finger which is pivotally mounted on a conductive support 52. Conductive support 52 has a concave portion which receives a mating convex portion of a finger 50 to form the pivot for the finger. A compression-type wipe spring 54 (FIG. 1) disposed between base 11 and each finger 50 acts on the finger to bias it in a counterclockwise direction about its pivot. For transmitting force between spring 54 and finger 50, there is provided a short rod 55 pivotally connected to the finger at 56 and having a shoulder 58 thereon against which spring 54 bears.

For carrying current between conductive stud 18 and the arcing contact finger 50, another conductive member 57 is provided. This member 57 extends alongside finger 50 and is connected at its lower end to stud 18 and at its upper end to conductive support 52. Current flowing between stud 18 and the lower end of contact 50 will follow a loop-shaped path that comprises two adjacent arms, one of which extends upwardly through member 57 and the other of which extends downwardly through parts 52 and 50. Current flowing through such a loop-shaped path will develop a repulsive magnetic effect between the arms of the loop which tends to force the arms apart. This repulsive magnetic force acts as a magnetic biasing force on finger 50 which tends to pivot it in a counterclockwise direction about its pivot.

Both the wipe spring 54 and the above-described magnetic biasing force tend to hold the arcing contact 50 in engagement with the movable arcing contact 49 when the circuit breaker is closed. During an opening operation, these forces drive the arcing contact 50 in follow-up relation to the movable arcing contact 49 and normally maintain engagement between the arcing contacts 49 and 50 until after the main contacts have parted. This results in current being transferred from the main contacts to the arcing contacts when the main contacts part. Shortly thereafter, the arcing contacts part, and this draws an arc between the arcing contacts that is lengthened as the arcing contacts rapidly separate. Suitable means is provided for driving this arc off the arcing contacts and into an arc chute 60 located thereabove, where it is extinguished. For simplicity, the arc chute, which may be conventional, is shown in outline form only.

For terminating follow-up motion of the stationary arcing contact 50 so that the movable arcing contact 49 can separate therefrom, a stationary stop 61 is provided for engaging contact 50 after a predetermined amount of such follow-up motion. When contact 50 engages stop 61, movable contact 49 separates from contact 50 to draw the above-described arc. Stop 61 is so positioned with respect to an arc runner 59 of the arc chute that when the arc is drawn, one of its terminals can promptly transfer to the arc runner 59 and move upwardly along the arc runner into the chute.

CROSS SHAFT 65 AND TOGGLES 66 COUPLING THE POLE UNITS TOGETHER

For coupling the pole units of the circuit breaker together so that the blades 14 of the pole units move in unison, a cross shaft **65** extending between the pole units is provided. Referring to FIG. **4**, this cross shaft **65** is mounted for angular movement about a stationarily located axis by suitable journal bearings **62*a*** provided at spaced locations in the frame **62** of the circuit breaker. Between cross shaft **65** and blade **14** of each pole unit, a toggle **66** is provided. These toggles **66** are substantially identical, and each comprises a pair of toggle links **67** and **68** pivotally interconnected by a knee pin **69**. At its opposite end, one toggle link **67** is pivotally connected by a pin **71** to blade **14**. The other toggle link **68** is mounted on cross shaft **65** and is suitably coupled to the cross shaft for angular motion therewith. As shown in FIG. **4**, each toggle link **68** comprises two segments spaced-apart along the cross-shaft **65** and suitably tied together for movement in unison.

It is to be noted that when the circuit breaker is fully closed as shown in FIG. **2**, each toggle **66** occupies a position in which its toggle links **67** and **68** are very close to dead center. In a preferred form of the invention the toggle is only about **9** degrees from dead center when the circuit breaker is fully closed. As shown in FIG. **2**, this angle is measured at *f* between a first plane that includes the central axis of cross shaft **65** and the central axis of knee pin **69** and a second plane that includes the central axis of the pivot pin **71** and the central axis of knee pin **69**.

CIRCUIT BREAKER OPENING

Circuit-breaker opening is effected by driving each toggle link **68** in a clockwise direction from its position of FIG. **2**. This causes each toggle **66** to move away from its dead center position of FIG. **2** toward its collapsed position of FIG. **1**. As the toggle moves away from dead center, the angle *f* increases. But at the instant the main contacts part, the toggle is still very close to dead center, the angle *f* then being only about 21° in a preferred form of the invention. The importance of having the toggle near dead center at this instant will soon be explained in more detail.

Part of the force for circuit breaker opening is derived from a tension-type opening spring **70** connected to one of the toggle links **68**. When spring **70** is permitted to discharge, as will soon be described, it drives its connected toggle link **68** in a clockwise opening direction about the axis of cross shaft **65**, carrying cross shaft **65** and the other toggle links **68** in a clockwise opening direction. Wipe springs **29** and **54**, associated with the stationary contacts, also provide opening force for driving blades **14** during an opening operation.

FLYWHEEL 72, 73

For controlling the opening speed of the contact blades **14** of the three pole units, a massive flywheel is coupled to the cross shaft **65** for angular motion therewith. In a preferred form of the invention, this flywheel comprises two stacks **72** and **73** of steel laminations respectively disposed at opposite ends of the cross shaft **65**. The laminations in each stack are suitably secured together and have a non-circular bore snugly fitting the cross shaft to force them to rotate with the cross shaft. The mass of flywheels **72, 73** is made sufficiently high that the total inertia of the cross shaft **65** and the flysheel **72, 73** is at least 10 times that of the total inertia of the stationary arcing contacts **50** of the three pole units of the circuit breaker. In a preferred embodiment of the invention, the stationary arcing contacts have a total inertia of about 48×10^{-4} lb sec^2 in., whereas the cross-shaft and the flywheel have a total inertia of about $1{,}100 \times 10^{-4}$ lb sec^2 in. In other words the total inertia of the cross shaft flywheel is about 23 times that of the stationary arcing contacts **50**. The inertia of a particular part in the above discussion is its inertia as considered about its own axis of rotation.

CIRCUIT BREAKER CLOSING

For closing the circuit breaker, a conventional trip-free closing mechanism is relied upon. This closing mechanism comprises a main toggle **80** comprising a pair of toggle links **81** and **82** pivotally interconnected by a knee pin **84**. The main toggle link **81** has its upper end pivotally connected at **85** to an arm on the previously described toggle link **68**. The other main toggle link **82** has its lower end pivotally supported on a pivot pin **86**. Pivot pin **86** is carried by guide link **88** that is pivoted on a fixed fulcrum **90**. Pivot pin **86** carries a latch roller **91** which cooperates with a suitable trip latch **92**.

So long as trip latch **92** remains in its latched position of FIGS. **1** and **2**, the main toggle **80** is capable of transmitting thrust to secondary toggle **66**. Thus, when the knee **84** of the main toggle is driven to the left from its position of FIG. **1** toward that of FIG. **2**, the main toggle **80** is extended, thereby applying to the secondary toggle link **68** a force which rotates this toggle link in a counterclockwise direction. This drives secondary toggle **66** toward dead center, thereby driving blade **14** through its counterclockwise closing stroke and also tensioning opening spring **70**.

For transmitting closing force to the toggle **80** as above described, a rotatable closing cam **100** is provided. This closing cam is keyed to a rotatable drive shaft **102**. When shaft **102** and cam **100** are rotated clockwise from their position of FIG. **1** through their position of FIG. **2**, the cam **100** acts on a roller **104** to extend the toggle **80**. A suitable prop **106**, freely rotatable on drive shaft **102** and biased in a counterclockwise direction by a tension spring **108**, falls in behind the roller **104** when the roller enters its closed position, thus holding toggle **80** extended and allowing cam **100** to continue rotating clockwise past its position of FIG. **2** without causing toggle **80** to collapse.

Should the trip latch **92** be tripped when the circuit breaker is at its closed position of FIG. **2** or even during a closing operation, toggle-support pin **86** will be freed from restraint by latch **92** and this will render main toggle **80** inoperative to continue transmitting closing thrust to the secondary toggle **66**. As a result, the opening spring **70**, assisted by wipe springs **29** and **54**, will drive the movable contact blade **14** into its open position of FIG. **1**, collapsing the main toggle **80** and driving guide link **88** in a counterclockwise direction about fulcrum **90**. As long as latch **92** is held tripped, toggle **80** will be unable to transmit closing thrust to the secondary toggle **66**. Resetting of the latch is effected by spring **94** when guide link **88** is reset from its tripped position into its position of FIG. **1** by a reset spring **95**.

RETARDING OPENING ACCELERATION AND VELOCITY DURING THE EARLY STAGES OF AN OPENING OPERATION

As pointed out in the introductory portion of this specification, it is highly desirable to completely transfer the current off of the main contacts **43**, **20** immediately after the main contacts separate during an interrupting operation. A factor that can interfere with the desired rapid current transfer is the tendency of the arcing contacts **49**, **50** to magnetically pop apart and draw an arc therebetween prior to complete transfer of current off the main contacts. Such contact-popping results from magnetic repulsion forces developed by current flowing through the arcing contacts.

To resist such contact popping, I rely upon two important relationships: (1) the presence of toggle **66** and the fact that the toggle is near dead center during the early stages of the opening operation and particularly at the instant the main contacts part and (2) the high inertia effect made available by the massive flywheel **72**, **73** on the cross shaft **65**. The combined effect of these two relationships is to severely limit the velocity and the acceleration of blade **14** during the early stages of the opening operation, especially during the period between the initiation of opening motion of blade **14** and the point at which the main contacts part. The stationary arcing contact structure **50** has a correspondingly reduced velocity and acceleration during this initial period of the opening operation; and this results in drastically reducing the amount of hold-closed force that is lost in accelerating the arcing contact structure **50** during this period. Accordingly, more hold-closed force is available to prevent magnetic popping-apart of the arcing contacts **49**, **50** during this crucial period.

Because the toggle **66** is near dead center during this crucial period, it will be apparent that a relatively large amount of cross-shaft **65** travel results in only a small amount of opening travel of blade **14**, thus limiting the velocity and acceleration of blade **14** during this period. The extent to which the cross-shaft **65** can be accelerated is limited by the inertia effect of the large flywheel mass **72**, **73** on cross-shaft **65**. An inertia mass located on cross-shaft **65** itself is far more effective in limiting acceleration of blades **14** than the same mass would be attached directly to blades **14**. There is, in effect, an inertia magnification that results from the presence of toggle **66**. This inertia magnification may be thought of as the ratio between the inertia (referred to the blade pivot **16**) of a given mass if applied to cross-shaft **65** and its inertia if applied instead directly to the blades **14**.

In one form of my invention, the inertia magnification at the start of an opening operation is over **50**. By the time the main contacts part, each toggle **66** has moved sufficiently away from dead center (about 21°) to reduce this inertia magnification to about **11**. By the time the arcing contacts part, each toggle is about 41° from dead center and this inertia magnification has been reduced to about 3. When the contacts are three-eighths inch apart and each toggle is 51° from dead center, this inertia magnification is about 2. As opening continues, the inertia magnification continues to drop, reaching about 0.4 when the circuit breaker is fully open.

Viewed in a slightly different way, the following relationship must be present to prevent contact popping:

$$F_s + F_m - F_a > F_p,$$

where

F_s is the spring force from springs **54** tending to hold the arcing contacts in engagement,

F_m is the magnetic force primarily from current through the loop **57**, **52**, **50** tending to hold the arcing contacts in engagement,

F_a is the force required to accelerate the arcing contact **50** to maintain engagement between the arcing contacts **50**, **49**, and

F_p is the magnetic force tending to produce popping,

all of said forces being forces referred to the point of arcing contact engagement. By keeping the acceleration of arcing contact **50** relatively low until the main contacts have parted, I am able to keep F_a relatively low during this period and thus reduce the extent which F_a detracts from the forces F_s and F_m that are available to hold the arcing contacts in engagement. Thus, with only relatively small springs providing the force F_s, I am able to provide sufficient hold-closed force to prevent contact-popping, even at high currents.

Because the above-described inertia magnification dropped sharply between the instant the main contacts **43**, **20** part and the instant the arcing contacts **50**, **49** part, the retarding effect of the flywheels **72**, **73** is relatively low at this instant. This enables separation of the arcing contacts **49**, **50** to proceed at high speed. Continued separation of the arcing contacts at high speed is further facilitated by the continued drop in inertia magnification factor as the arcing contacts continue to move apart.

Had the large mass been attached directly to the blades **14**, this continuing drop in inertia magnification factor would not be available, and such large mass would retard actual separation of the arcing contacts much more severely than a corresponding mass on the cross-shaft **65**.

Rapid separation of the arcing contacts is highly desirable since this enables the arc formed therebetween to be rapidly lengthened, thus facilitating its rapid movement into the arc chute where it is interrupted.

ADDITIONAL DISCUSSION

During a circuit breaker closing operation, the presence of the flywheel **72**, **73** on cross-shaft **65** is very helpful in providng force for driving the contacts into their fully-closed position against the magnetic opposing forces developed by fault current. By the time the arcing contacts **49**, **50** first touch, which initiates fault current, a large percentage of the previously applied closing energy has been converted into kinetic energy in the flywheel, which is available to drive the contacts fully closed. Moreover, since the toggle **66** is near dead center at this point in the closing operation, there is a high mechanical advantage for closing forces transmitted therethrough to the contacts.

I am aware that there have been prior proposals to add mass to a closing cam such as my cam **100** to improve closing on fault currents. While this approach improves closing performance, it has no effect on opening perform-ance since this cam is free to remain inactive during an opening operation.

For dissipating the kinetic energy remaining at the end of an opening operation, I provide the flywheel **72**, **73** with a projection **110** that engages a suitable stationary buffer **112** at the end of the opening operation. For dissipating the kinetic energy remaining at the end of a closing operation, the flywheel **72** is provided with another projection **114** that engages the opposite side of the buffer at the end of the closing operation.

In the illustrated embodiment I transfer current directly from the main contacts to the arcing contacts. In other embodiments (not shown) it may be desirable to provide intermediate contacts which may receive a portion of the current transferred off the main contacts upon their separation. These intermediate contacts remain in engagement after the main contacts part, but they themselves part prior to parting of the arcing contacts. Such intermediate contacts are conventional and can be provided by modifying the upper set of main contacts to serve this purpose. All that is necessary in this respect is to provide a stop **27** for these latter contacts which is positioned to allow them to stay in engagement after the main contacts separate but to force their disengagement before the arcing contacts separate. These intermediate contacts are preferably made of an arc resistant material, such as one containing a refractory metal, whereas the main contacts are made of a higher conductivity material which has no refractory metal therein. Typically, silver is used for the main contacts both in the illustrated embodiment and in this modified embodiment.

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

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

1. An electric circuit breaker comprising a plurality of pole units, each comprising:

a. a set of relatively movable main contacts, engaged when the circuit breaker is closed, for normally carrying the principal current passing through the closed circuit breaker,

b. first and second relatively movable arcing contacts, engaged when the circuit breaker is closed, to which the principal current is transferred from said main contacts during the early stages of a circuit-breaker opening operation,

c. a movable blade on which one of said main contacts and the first of said arcing contacts is carried,

d. means for mounting the second of said arcing contacts for limited motion so that it can remain in engagement with said first arcing contact until said main contacts have parted during an opening operation,

e. spring means biasing said second arcing contact in a direction to oppose disengagement of said arcing contacts whenever they are engaged,

said circuit breaker further comprising:

f. a cross-shaft mounted for angular motion for coupling the blades of said pole units together,

g. a plurality of toggles respectively connected between said cross-shaft and the blades of said pole units, each toggle comprising a pair of pivotally interconnected links, one of which is pivotally connected to its associated blade and the other of which is coupled to said cross-shaft for angular motion therewith, each of said toggles occupying when the circuit breaker is open a first position wherein said toggle links are displaced from dead center by a relatively large angular distance and occupying when the circuit breaker is closed a second position wherein said toggle links are disposed near dead center of said toggle,

h. each of said toggles being movable from said first to said second position during a closing operation and from said second to said first position during an opening operation,

i. each of said toggles being within **25** degrees of dead center at the instant said main contacts part during an opening operation,

j. and a massive flywheel coupled to said cross-shaft for angular motion therewith, said cross-shaft and said flywheel having a combined inertia that is at least about ten times as large as the total inertia of all of said second arcing contacts of the plurality of pole units.

2. The circuit breaker of claim **1** in which each of said pole units comprises means for forcing current flowing through said engaged arcing contacts to follow a path adjacent said second arcing contact of such a shape that current therethrough develops a magnetic biasing force on said second arcing contact acting in a direction to hold said second arcing contact in engagement with said first arcing contact.

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

a. each of said blades is pivotally mounted on a pivot,

b. at any point in an opening operation there is present an inertia magnification equal to the ratio between the inertia, referred to said pivot, of a given mass if applied to said cross-shaft and its inertia if applied directly to said blades,

c. said inertia magnification remains above about 10 between the start of an opening operation and the point of main-contact-part.

4. The circuit breaker of claim **3** in which said inertia magnification is reduced to approximately 3 when the arcing contacts part at a later point in the opening operation. said cross-shaft and the blades of said pole units, each

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