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Kroon

[11] **3,777,291**

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[54] **ELECTRIC SWITCH WITH MAGNETIC-ASSIST MEANS TO ASSIST SWITCH IN CLOSING AND REMAINING CLOSED AGAINST HIGH CURRENTS**

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[52] **U.S. Cl.** **335/16**

[51] **Int. Cl.** **H01h 77/10**

[58] **Field of Search**..... 335/16, 15, 195, 335/191; 317/12 R

[56] **References Cited**

UNITED STATES PATENTS

2,601,417	6/1952	Scott, Jr.	335/16
3,319,121	5/1967	Lee	317/12 R
3,366,900	1/1968	Barkan	335/15
3,663,906	5/1972	Barkan et al.	335/195

Primary Examiner—Harold Broome
Attorney—J. Wesley Haubner et al.

[57] **ABSTRACT**

An electric switch includes magnetic-assist means for assisting the switch in closing and remaining closed against high currents. The magnetic-assist means develops a magnetic force acting in a switch-closing direction, even when the switch contacts are substantially fully separated. A toggle-type linkage connected between the magnetic-assist means and the movable contact of the switch limits to a relatively low value the portion of the magnetic force transmitted to the movable contact until the movable contact has passed through a substantial portion of its closing stroke.

11 Claims, 4 Drawing Figures

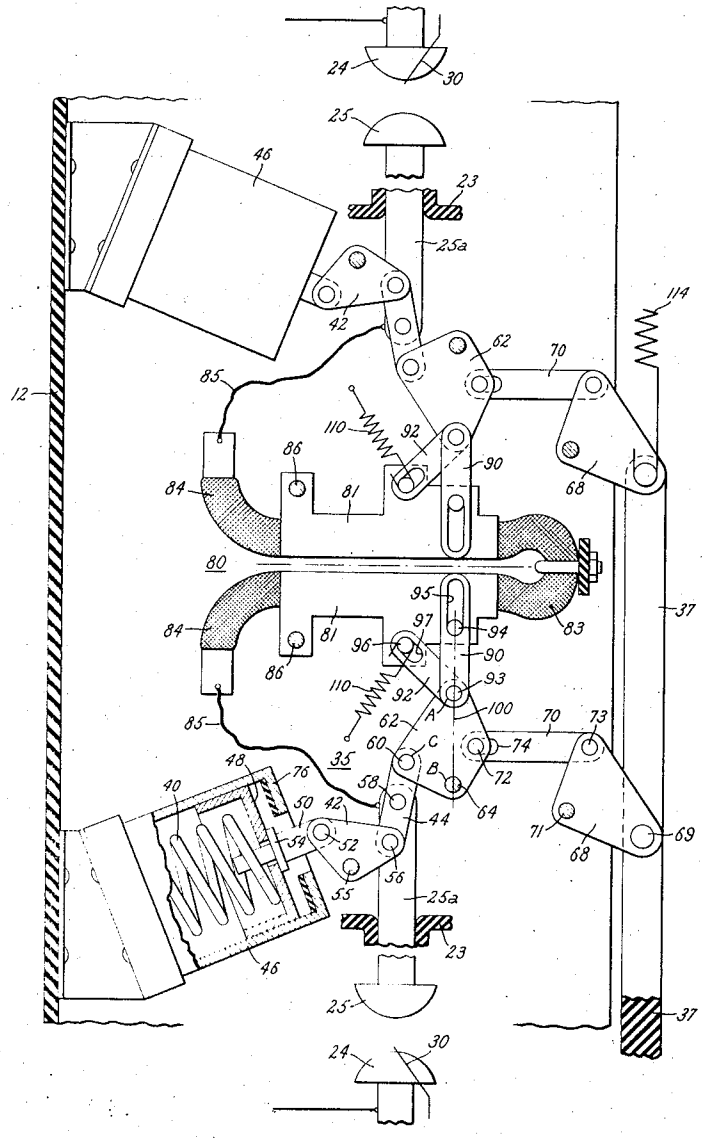


Fig. 1.

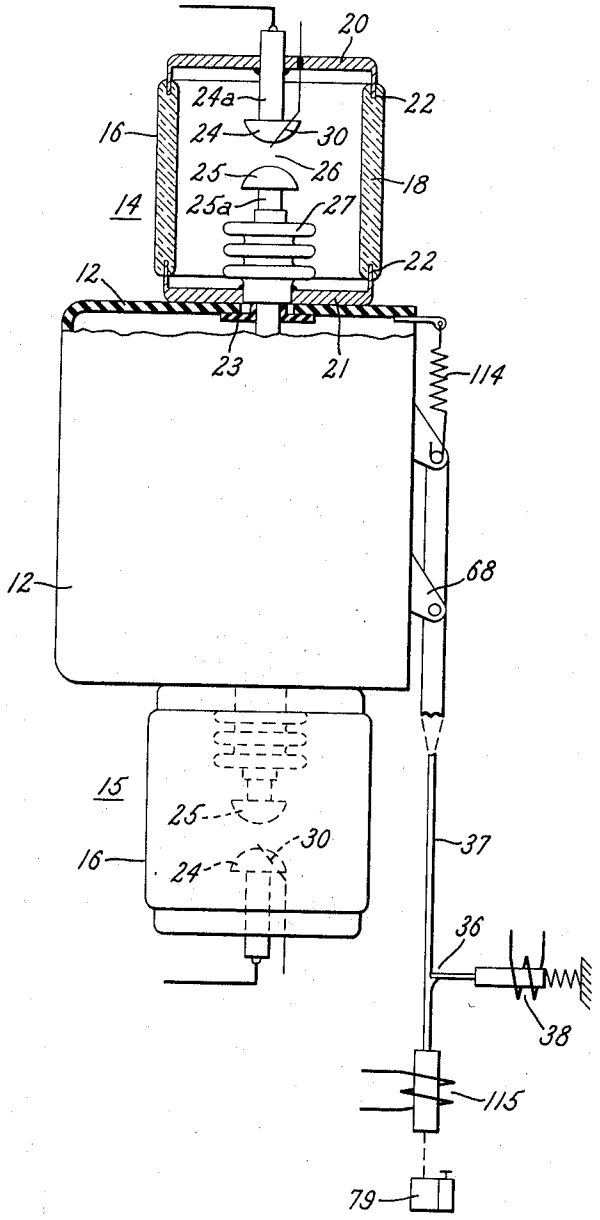

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24a
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16
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18
14
25a
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114
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68
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25
30
16
24
37
36
38
115
79

Fig. 2.

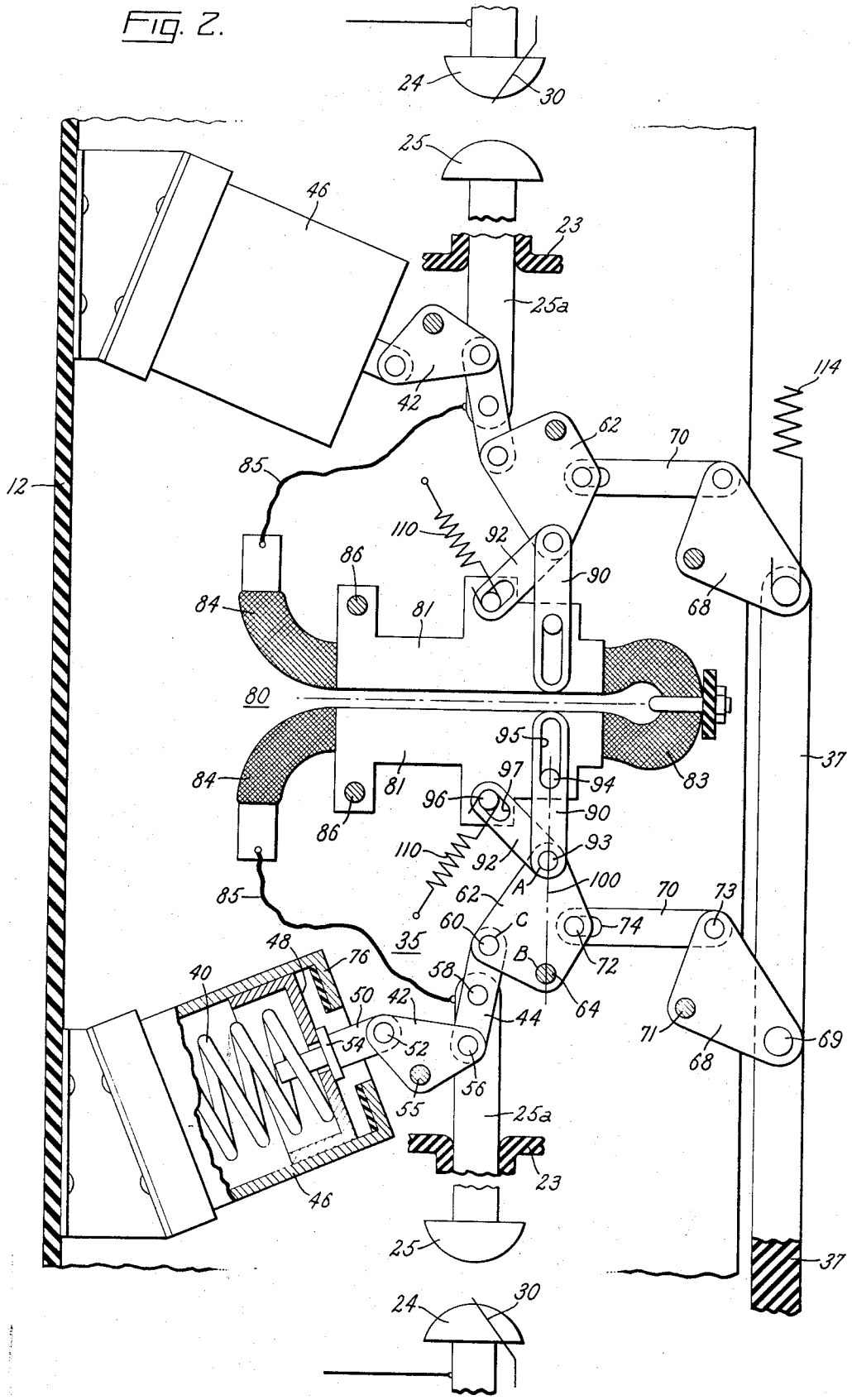

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23
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114
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70
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12
110
92
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84
81
68
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37
97
94
83
96
93
100
A
62
70
73
C
60
74
35
48
76
B
72
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50
42
58
64
44
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52
56
71
69
68
55
25a
23
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Fig. 3.

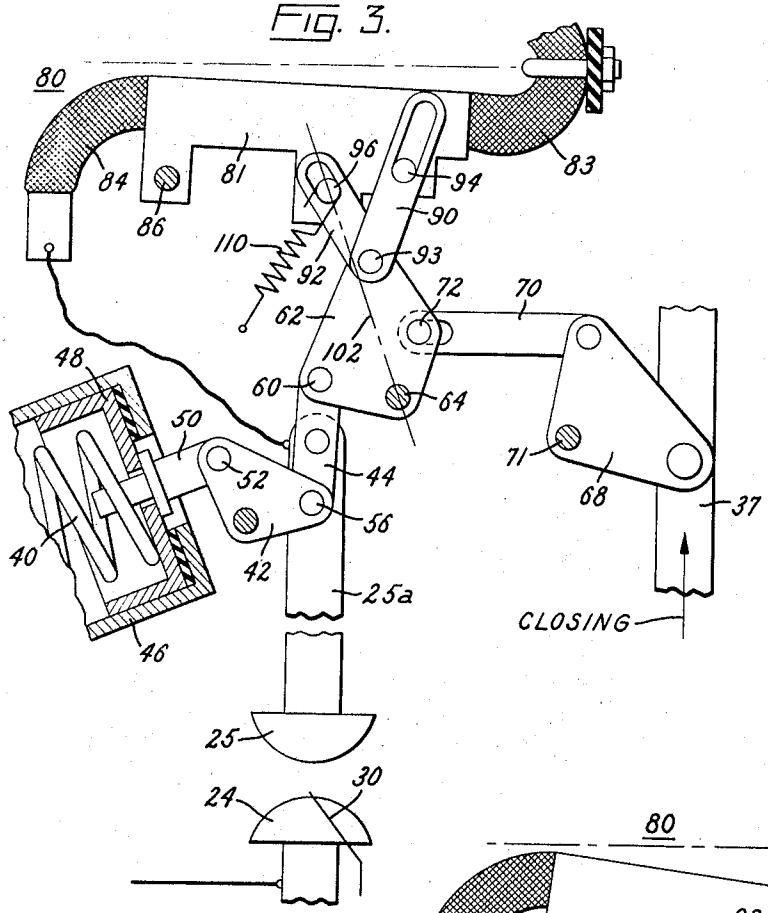
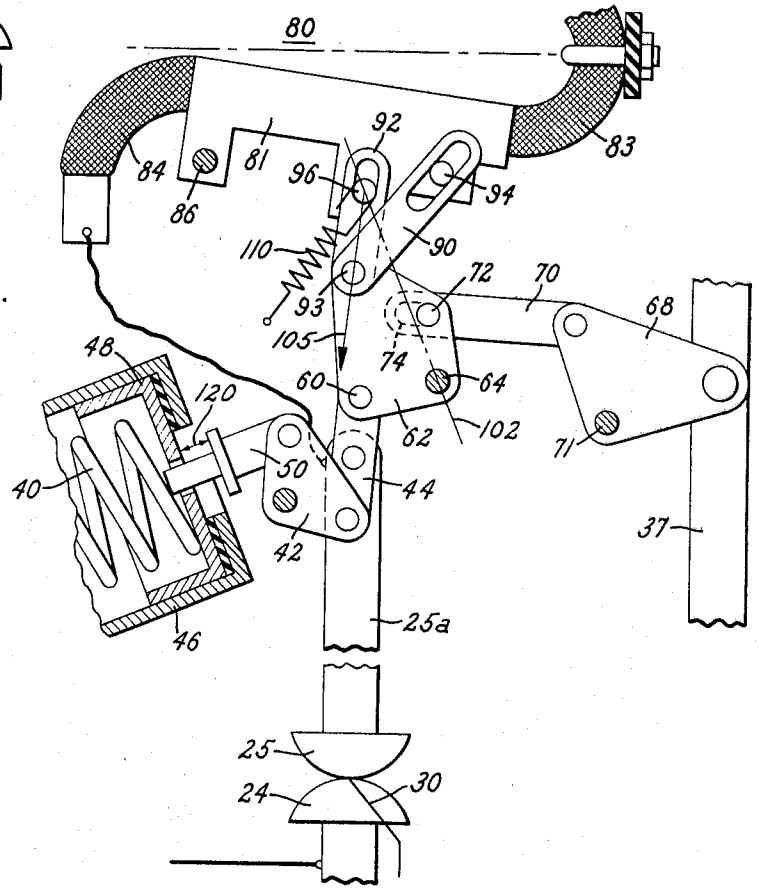

80
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81
86
96
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83
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110
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50
52
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42
46
25a
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CLOSING
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24
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Fig. 4.


80
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81
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120
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25a
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ELECTRIC SWITCH WITH MAGNETIC-ASSIST MEANS TO ASSIST SWITCH IN CLOSING AND REMAINING CLOSED AGAINST HIGH CURRENTS

BACKGROUND

This invention relates to an electric switch that includes magnetic-assist means to assist the switch in closing and in remaining closed against high currents and, more particularly, relates to magnetic-assist means that is especially adapted for use in a switch in which high currents can flow therethrough at the start of or during the early stages of a closing operation, even though the switch is in or near its fully-open position.

When high current flows through the engaged contacts of a typical switch, high magnetic forces are developed that tend to force the contacts apart. As explained in more detail in U.S. Pat. No. 3,225,160-Barkan, assigned to the assignee of the present invention, these forces result primarily from the tendency of the current path to restrict at the point of contact engagement and, thus, to develop loop-shaped components, each comprising arms extending along confronting faces of the contacts. Current through these loop-shaped components creates a repulsive, contact-separating force between the arms of each loop. These contact-separating forces, which are referred to hereinafter as "contact-popping" forces, vary directly with the square of the current and, hence, can be very high when currents of short circuit magnitude pass through the engaged contacts.

For opposing these contact-popping forces developed when high currents pass through the engaged contacts, various electromagnetic arrangements have been devised which act on the contacts to hold them engaged with a force also varying directly with the square of the current through the contacts. In certain of these electromagnetic arrangements, referred to hereinafter as magnetic-assist arrangements, a current-dependent magnetic force is developed and applied to the movable contact in a switch-closing direction whenever current flows through the contacts, irrespective of contact position at the time current begins flowing. Generally speaking, however, this magnetic-assist force is not needed unless the contacts are engaged, or just about to engage, at the end of a closing stroke. It is only when the contacts are engaged that the high contact-popping forces are developed. If magnetic-assist force proportional to the square of short circuit current is applied to the contacts during the entire closing stroke, there is a tendency to produce unpredictable and unduly high closing speeds.

In most switches, the development of the magnetic-assist force is automatically delayed until the instant needed inasmuch as no current flows through the contacts during a closing stroke until the contacts engage or are about to engage at the end of the closing stroke. This automatic delay, however, is not present in the switch application that the present invention is concerned with. In this particular switch application, the switch has triggering means which is operable to cause current to flow between the contacts even when they are in or near their fully-separated position. An example of this type of switch application is illustrated in U.S. Pat. No. 3,319,121-Lee, assigned to the assignee of the present invention.

SUMMARY

A general object of my invention is to provide magnetic-assist means which is especially adapted for use in a switch application in which current can flow through the switch contacts at the start of or during the early stages of a switch-closing operation, even when the contacts are in or near their fully-separated position.

Another object is to provide magnetic-assist means which, though it develops a force varying directly with current magnitude when the contacts are fully-separated, is controlled in such a manner that only a small portion of said force acts in a closing direction on the movable contact of the switch when the movable contact is in or near its fully-separated position.

Another object is to provide means for rapidly accelerating the movable contact in a closing direction at the start of the closing stroke which provides an accelerating force that is independent of current magnitude and which is ineffective to oppose high-speed opening motion at the start of a subsequent opening stroke.

Another object is to construct the magnetic-assist means in such a manner that a single magnetic-assist means can serve to hold closed the contacts of two separate circuit interrupters against the high contact-popping forces developed when a high current flows through the two interrupters.

In carrying out my invention in one form, I provide an electric switch that comprises a first contact, a second contact that is movable into and out of engagement with the first contact, and triggering means operable to cause current to flow between said contacts while the contacts are substantially fully separated and during substantially an entire closing stroke. The switch further comprises magnetic-assist means for developing for transmission to said second contact a magnetic force acting in a switch-closing direction which varies directly in accordance with the current through said contacts. Means is provided for transmitting said magnetic force from said magnetic-assist means to the second contact which includes means for limiting to a relatively low value the portion of the magnetic force transmitted when the contacts are in and near their fully-separated position but transmitting a relatively large portion when said contacts are in and near their fully closed position. Spring means controlled by a suitable latch is provided for biasing the second contact toward closed position when the contacts are fully separated and the latch is released.

BRIEF DESCRIPTION OF DRAWINGS

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

FIG. 1 is a side elevational view, partly in section and partly schematic, showing a switch embodying one form of my invention.

FIG. 2 is a schematic side elevational view of switch-operating means constituting a part of the switch of FIG. 1. In FIG. 2 the switch is depicted in its fully-open position.

FIG. 3 shows the switch-operating means of FIG. 2 in a position through which it passes at an intermediate point in a switch-closing operation.

FIG. 4 shows the switch-operating means of FIG. 2 in the position it occupies when the switch is fully closed.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Triggered Interrupters 14 and 15

Referring now to FIG. 1, the switch shown therein comprises a stationary housing 12 for the operating mechanism of the switch and two vacuum-type circuit interrupters 14 and 15 fixed to opposite sides of the housing.

Each vacuum interrupter is a triggered vacuum interrupter of a general type shown and claimed in the above-mentioned U.S. Pat. No. 3,319,121-Lee. As such, each interrupter comprises a sealed envelope 16 that is evacuated to a pressure of 10^{-4} torr or lower. The envelope 16 comprises a cylindrical casing 18 of a suitable insulating material and a pair of metallic end caps 20 and 21 at opposite ends of the casing. Suitable seals 22 are provided between the end caps and the casing to provide a vacuum-tight joint between these parts.

Located within each evacuated envelope 16 is a pair of main electrodes 24 and 25 that are normally spaced apart to define a main or primary gap 26 located therebetween. Electrode 24 is a stationary electrode which is supported on the outer end plate 20 by means of stationary supporting rod 24*a*; whereas electrode 25 is a movable electrode which is joined to and carried by an elongated conductive operating rod 25*a* that projects through an opening in the inner end plate 21. A flexible metallic bellows 27 is provided about operating rod 25*a* to permit vertical movement thereof without impairing the vacuum inside envelope 16. Bellows 27 is secured by suitable seals at its respective opposite ends to operating rod 25*a* and end plate 21.

For each interrupter, a stationary guide 23 is provided for slidably receiving the movable contact rod 25*a* and thereby guiding it for motion along a straight line vertical path.

Under normal conditions, there is a high voltage present between main electrodes 24 and 25, but no current flows therebetween since the main gap 26 normally has sufficient dielectric strength to withstand this voltage without breakdown.

For causing the main gap 26 to break down in response to predetermined conditions, there is provided a trigger electrode (schematically shown at 30) suitably insulated from main electrode 24. Between this trigger electrode 30 and main electrode 24, there is a trigger gap which is sparked over when a predetermined voltage is applied between the trigger electrode and the main electrode. The resulting sparkover produces ionized vapors which are rapidly injected into the main gap 26 to reduce its dielectric strength, thus allowing the voltage that is then present between the main electrodes 24 and 25 immediately to produce an arc-over of the main gap 26. Reference may be had to the aforesaid Lee patent for a more detailed description of the trigger gap and its mode of operation.

Operating Mechanism 35

To prevent the electrodes 24 and 25 from being damaged by the above-described arc-over and to provide a solid metallic path through the switch, the movable electrode 25 is rapidly driven into engagement with stationary electrode 24 immediately following arc-over. The force for producing this closing motion of electrode 25 is developed by an operating mechanism 35 (shown in FIG. 2) located within housing 12. The operating mechanism is a stored-energy type device, operation of which is initiated by releasing a suitable latch or restraining means (shown schematically at 36 in FIG. 2) coupled to the operating mechanism through a vertically-extending control rod 37 of insulating material. The illustrated latch 36 is controlled by a solenoid 38 which is adapted to be energized in response to current flow of a predetermined value between the main electrodes 24, 25 thereby releasing the latch and allowing the operating mechanism 35 to operate.

Referring now to FIG. 2, the operating mechanism 35 comprises two sub-assemblies of substantially identical construction, only one of which, the lower sub-assembly, will be described in detail. This sub-assembly comprises a compression spring 40 which is coupled to a crank 42 which, in turn, is coupled to movable contact rod 25*a* through a connecting link 44. Compression spring 40 is located within a cylinder 46 and bears at one end against the rear wall of the cylinder and at its opposite end against a piston-like guide member 48 slidably mounted in the cylinder. Guide member 48 contains a centrally-located hole in which one end of a push rod 50 is slidably mounted. Push rod 50 is pivotly connected at its opposite end to the crank 42 by a pivot pin 52 and has a shoulder 54 thereon against which guide member 48 bears when the parts are in the position of FIG. 1.

Crank 42 is pivotally mounted on a stationary pivot 55 and is coupled to the connecting link 44 through a pivot pin 56. Intermediate its ends, the connecting link 44 is pivotally connected to contact rod 25*a* through a pivot 58; and at one end, the connecting link 44 is pivotally connected at 60 to a main toggle link 62. Toggle link 62 is pivotally mounted on a stationary pivot 64 and is coupled to the vertically-extending control rod 37 through a linkage comprising a crank 68 and a tension member 70. Crank 68 is pivotally mounted on a stationary pivot 71 and has one arm pivotally connected at 69 to control rod 37 and its other arm pivotally connected at 73 to tension member 70. Tension member 70 is pivotally connected to toggle link 62 through the pin and slot connection comprising a pin 72 on a toggle link and a slot 74 in the tension member 70.

It will be apparent from the above that when the parts are in the position of FIGS. 1 and 2 the compression spring 40, acting through elements 50, 42, and 44 is biasing the movable contact rod 25*a* in a downward closing direction but is restrained from so moving the contact rod by latch 36 (FIG. 1) acting through the parts 62, 70, 68, and 37 to hold these latter parts in their illustrated position. When the latch 36 is released, parts 62, 70, 68, and 37 are no longer so restrained, and the compression spring 40 is thus free to drive movable contact rod 25*a* in a closing direction. Compression spring 40 continues this driving action until its guide member 48 encounters a stationary buffer 76 on the cylinder 46. When this occurs, the inertia of the moving parts (with certain assistance, soon to be described) continues the closing operation, carrying the parts through their position of FIG. 3 into their fully-closed position of FIG. 4.

A suitable conventional dashpot 79 acts near the end of the closing stroke to decelerate the mechanism and limit the contact velocity on impact to the desired range. This dashpot does not significantly affect opening speeds.

Magnetic-Assist Means 80

When the contacts first touch at the end of a closing stroke, magnetic forces (referred to herein as contact-popping forces) proportional to the square of the current are abruptly established, which forces act in a direction to drive the contacts apart and oppose the force tending to hold them closed. These contact-popping forces are explained in more detail in the introductory portion of this application. Typically, the switch will be closed against very high currents, and thus extremely high contact-popping forces are developed at or near the end of the closing stroke.

For overcoming these high contact-popping forces, magnetic-assist means **80** is provided. This magnetic-assist means comprises two identical bars **81** of electroconductive material which are electrically connected in series with each other and with the contacts of the two interrupters. For connecting the two bars **81** in series with each other, a flexible conductive braid **83** is connected between the adjacent right hand ends of the bars. Additional braid **84** is provided at the left hand end of each bar, and each of these braids **84** is electrically connected to its associated movable contact rod **25***a* by means of a conductor schematically shown at **85.** Each of the bars **81** is mounted on a stationary pivot pin **86.** When current flows through the bars **81** via the interconnecting braid **83,** it passes in opposite directions through the bars; and this results in a magnetic repulsive force being developed therebetween tending to force the bars apart by pivoting them in opposite angular directions about their associated pivots **86.**

Toggles Linkages **90, 62** and **92, 62**

The force developed by magnetic assist means **80** is transmitted to the movable contact rod **25***a* of each interrupter by linkage means comprising two toggle links **90** and **92,** which come into play sequentially, as will soon be described. Referring to the lower subassembly, the first toggle link **90** is pivotally connected at its lower end to previously-described main toggle link **62** by a pivot pin **93** and is pivotally connected at its upper end to the bar **81** through a pin and slot connection **94, 95.** The second toggle link **92** is pivotally connected at its lower end to the main toggle link **62** and is pivotally connected at its upper end to the bar **81** by means of a pin and slot connection **96, 97.**

When the parts are in a position of FIG. **2,** the first toggle link **90** and the main toggle link **62** are relied upon for transmitting force from the magnetic-assist means **80** to the movable contact rod **25***a*. The second toggle link **92** is then inactive. But when the closing operation has reached the point depicted in FIG. **3,** the first toggle link **90** drops out of play and the second toggle link **92** comes into play. To explain this more specifically with reference to the lower sub-assembly, when the parts are in the position of FIG. **2,** the magnetic-assist means **80** forces the pin **94** downwardly against the bottom of slot **95** in link **90,** thus transmitting force from magnetic-assist means **80** through link **90.** This driving relationship at **94, 95** continues while the parts are moving through a closing stroke from their position of FIG. **2** to that of FIG. **3;** but when the parts pass beyond their position of FIG. **3** toward their position of FIG. **4,** the lower wall of slot **95** of link **90** moves out of engagement with pin **94,** thus interrupting the previously-existing driving relationship at **94, 95.**

During the above-described closing motion that carried the parts between their positions of FIG. **2** and FIG. **3,** no driving force was transmitted through second toggle link **92** because pin **96** remained spaced from the bottom of slot **97** in the second toggle link. But when the parts entered their position of FIG. **3,** the bottom of slot **97** and pin **96** engage, and thereafter force from the magnetic-assist means **80** is transmitted to main toggle link **62** through the second toggle link **92.**

While the parts are in their position of FIG. **2** and while moving between their positions of FIGS. **2** and **3,** the links **90** and **62** are acting as a toggle, the knee of which is the pin **93** which joins links **90** and **62.** This toggle is substantially on center when in the position of FIG. **2** inasmuch as knee pin **93** is located on the toggle center line **100** interconnecting the axes of pins **64** and **94.** The knee **93** moves away from center line **100** as the parts move in a closing direction toward their position of FIG. **3.** As a result of the initial on-center relationship of toggle **90, 62,** the magnetic-assist forces are substantially completely blocked and no substantial force is applied to the main toggle links **62** in a direction to rotate it. But as the toggle **90, 62** moves off center toward its position of FIG. **3,** the toggle **90, 62** becomes progressively more capable of rotating link **62** in a counterclockwise closing direction. When the position of FIG. **3** is reached, the toggle **90, 62** becomes ineffective, as abovedescribed; and a new toggle, formed by links **92, 62** and knee pin **93** and having a center line **102,** becomes effective. In the position of FIG. **3,** toggle **92, 62** is very close to, or even slightly under, dead center, and thus the effectiveness with which closing forces are transmitted from the magnetic-assist means **80** to the main toggle lever **62** is again at a very low level. After continued closing motion, however, toggle knee **93** moves across and then progressively further away from the toggle center line **102,** thus rendering toggle **92, 62** progressively more effective in transmitting closing force from the magnetic assist means **80** to main toggle link **62.** Note in FIG. **4** the relatively large distance then present between the toggle knee **93** and center line **102,** resulting in relatively great effectiveness of the toggle when transmitting closing and hold-closed forces to the contact rod **25***a*.

Functions of Toggle Linkages

It will be apparent from the above description of toggles **90, 62** and **92, 62** that they cooperate to limit to a low level the closing force transmitted from magnetic-assist device **80** to movable contact rod **25***a* until near the end of the closing stroke. One of my reasons for limiting this force until near the end of the closing stroke is that high magnetic closing force is needed only when the contacts are in or very near engagement since this is the only time when high contact-popping forces, which tend to separate the contacts, are developed. Another reason is that I desire to minimize the variations in closing speed resulting from the different values of magnetic force developed by the magnetic-assist means **80.** In this respect, it should be noted that the repulsive force developed between the two bars **81** of the magnetic-assist device is directly dependent upon the level of current flowing there through. In a triggered interrupting device such as I am dealing with, current flow is initiated while the interrupter is still fully open, and thus this current-dependent repulsive

force between bars **81** is developed while the switch is still fully open. If this repulsive force was transmitted without reduction to the movable contact rod **25***a*, variations therein would have a much more pronounced effect on closing speed than occurs in my arrangement, where only a small portion of this repulsive force is transmitted to the movable contact rod during the early stages of closing. In my arrangement, the force for initial closing motion is supplied principally by closing spring **40**, and this is a force that is independent of current variations. In other words, the total closing force during the first portion of a closing action comprises a large current-independent major component (from spring **40**) and another component that, though current dependent, is held to a minor and relatively insignificant value in relationship to the total by the toggle action described hereinabove.

In certain applications of my switch, it is very desirable that the contacts **24, 25** reach engagement at an instant near current zero of the alternating current wave. It is much easier to achieve this result if the closing speed is predictable and not subject to major variations as a result of differences in current. Since my closing speed during much of the closing stroke is not drastically affected by current variations, as has been pointed out above, I am able to provide a more predictable closing speed that enables me to more consistently reach contact-engagement near current zero.

A factor which contributes to the effectiveness of the toggle **92, 62** in transmitting closing force to the movable contact when the contacts are in their engaged position of FIG. **4** is the mechanical advantage that it provides in transmitting force from the magnetic-assist device **80** to the contact rod **25***a*. In this regard, not that when the switch is in its closed position of FIG. **4**, the force from the magnetic-assist device is transmitted along the path of an arrow **105**. The effective lever arm of this force path, as measured from stationary pivot **64** to the arrow **105** normal thereto, is considerably greater than the distance between pivots **60** and **64**. This results in a mechanical advantage equal to the ratio of the longer to the shorter lever arm, thus enabling a given repulsive force developed in the magnetic-assist device to exert a considerably larger force on the movable contact **25**. This mechanical advantage enables a smaller magnetic-assist device to be used for developing the needed hold-closed force at the contacts.

Another factor which enables a magnetic-assist device of relatively small size to be used is that the bars **81**, between which the repulsive magnetic force is developed, remain relatively close together even when the movable contact **25** has been moved through its full closing stroke. The relatively short stroke of the magnetic-assist device results from the fact that the toggles **90, 62** and **92, 62** operate for the most part near dead center, as well as from the fact that the interrupting devices **14** and **15**, being of the vacuum type, have very short strokes.

Other Features

It is to be noted that the closing spring **40**, in driving the operating mechanism during the early portion of the closing operation, does not dissipate any of its energy in accelerating the relatively massive parts of the magnetic-assist device **80**. In this regard, the slots **95** and **97** in the toggle links **90** and **92** permit these parts **90, 92** to be driven by the closing spring free of the bars **81**. The bars are moved in follow-up relationship to these links **90** and **92** by the above-described repulsive magnetic force between the bars **81** and also by auxiliary closing springs **110**, soon to be described.

The auxiliary closing springs **110** serve also to hold the contacts of the interrupters in engagement under light-current or no-current conditions when they are standing in engagement. These auxiliary closing springs are shown as tension springs, each connected between a stationary point and a pin **96** on one of the bars **81**. Under light current or no current conditions, little or no hold-closed force is developed by the magnetic-assist device; but the auxiliary springs **110** provide a hold-closed force that assures that the contacts will remain in engagement with sufficient contact pressure until the mechanism is deliberately operated in an opening direction.

When each of the movable contacts **25** engages its stationary contact at the end of a closing stroke, the latching linkage **70, 68, 37**, which had been moving in follow-up relationship to the main toggle link **62**, continues moving in the same direction for a short additional distance, driven primarily by a follow-up spring **114** connected to the vertical rod **37**. This added motion moves each of the two tension members **70** further to the left into the position of FIG. **4**, as permitted by the slot **74** in each tension member **70** sliding on pin **72**. Finally, the latching linkage **70, 68, 37** encounters a suitable stop (not shown) which terminates its motion. The slotted connections **74, 72** permit the two movable contacts **25** to seat independently of each other without restraint from the latching linkage **70, 68, 37** and its stop.

For opening the switch, an opening operator such as the solenoid schematically shown at **115** in FIG. **1** is provided. This solenoid, when energized, drives the contact rod **37** downwardly from its closed position (not shown) into its open position of FIG. **1**, where the control rod **37** is then held by latch **36**. During the early part of such opening motion, the slotted portion **74** of each tension member **70** slides over the pin **72**, imparting no opening force to the associated movable contact **25** until the left hand end of the slot **74** impacts against the pin **72**. This impact is applied through links **70, 62, 44** to the contact rod **25***a* and serves the desirable function of breaking any welds that might then be present between the contacts. Further motion of the linkage **70, 68, 37** carries the movable contact **25** through its opening stroke.

In the circuit applications in which my switch is applied, opening is effected only when there is a relatively low current through the contacts. This means that the magnetic-assist means **80** is not then developing a high force opposing contact separation, thus enabling a solenoid **115** of reasonable size to be used for producing opening.

Another factor that reduces the force requirements imposed on the opening solenoid **115** during the opening operation is the fact that the closing spring **40** does not oppose initial opening action since it was snubbed by stop **76** during the preceding closing action well before the closing stroke was completed. As a result, during the opening operation the push rod **50** is able to move through travel depicted at **120** in FIG. **4** before the closing spring (**40**) begins to exert any opposition to the opening action.

It is to be noted that in the disclosed operating means there are virtually no mechanisms or actuators which require resetting between the end of an opening stroke and the start of a closing stroke. Closing can commence as soon as the movable contacts **25** has reached its fully-open position and the latch **36** (of FIG. 1) is tripped. Likewise, opening can occur as soon as the contacts reach their closed position of FIG. **4**.

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 the invention in its broader aspects, and I, therefore, intend in the appended claims 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 switch comprising:

a. a first contact and a second contact that is movable into and out of engagement with said first contact,

b. triggering means operable to cause current to flow between said contacts while said contacts are substantially fully-separated,

c. magnetic-assist means for developing for transmission to said second contact a magnetic force acting in a switch-closing direction which varies directly in accordance with the current through said contacts,

d. means for transmitting said magnetic force from said magnetic-assist means to said second contact comprising means for limiting to a relatively low value the portion of the magnetic force transmitted when said contacts are in and near their fully-separated position but transmitting to said second contact a relatively large portion of said magnetic force when said contacts are in and near their fully-closed position,

e. spring means biasing said second contact toward closed position when said contacts are fully separated, and

f. releasable restraining means for holding said second contact in said fully-separated position against the bias of said spring means and releasable to permit said spring means to drive said second contact toward engaged position.

2. The switch of claim **1** in which:

a. said spring means comprises a closing spring that discharges during the early stages of a switch-closing operation to accelerate said second contact in a switch-closing direction, and

b. snubbing means is provided for blocking said spring from further discharging at a point substantially ahead of the point at which said contacts engage during a switch-closing operation.

3. The switch of claim **1** in which:

a. said means for limiting the force transmitted from said magnetic assist means comprises a toggle linkage connected between said magnetic-assist means and said second contact which operates near an on-center position when said second contact is near its fully-separated position,

b. said toggle linkage having a portion serving as an output end during a closing operation through which forces from said magnetic-assist means are transmitted to said movable contact,

c. the toggle linkage being so constructed that the portion of the input force transmitted therethrough to said output end is relatively low when said toggle linkage is operating near its on-center position compared to that portion transmitted when the toggle linkage is operating further away from its on-center position.

4. The switch of claim **1** in which:

a. said means for limiting the force transmitted from said magnetic-assist means to said second contact comprises first and second toggle linkages, both of which are connected between said magnetic-assist means and said second contact,

b. said first toggle linkage being effective to transmit force from said magnetic-assist means to said second contact when said contacts are near their fully-separated position,

c. said second toggle linkage being ineffective to transmit force from said magnetic-assist means to said second contact when said contacts are near their fully-separated position,

d. means operable after the first stages of a switch-closing operation for rendering said first toggle linkage ineffective and said second toggle linkage effective to transmit force from said magnetic-assist means to said second contact,

e. said second toggle linkage operating near its on-center position when it first becomes effective and operating further away from said on-center position as the switch-closing operation progresses,

f. said second toggle linkage having a portion serving as an output end during a switch-closing operation through which forces from said magnetic-assist means are transmitted to said movable contact,

g. said second toggle linkage being so constructed that the portion of the input force transmitted therethrough to said output end is relatively low when said second toggle linkage is operating near its on-center position compared to that portion transmitted when said second toggle linkage is operating further away from its on-center position.

5. The switch of claim **4** in which said first toggle linkage is substantially on-center when said contacts are fully separated and remains near center during the closing operation until said second toggle linkage becomes effective, said first toggle linkage having a portion serving as an output end during a closing operation through which forces from said magnetic-assist means are transmitted to said movable contact when said first toggle linkage is effective, and said first toggle linkage being so constructed that the portion of the input force transmitted therethrough to said output end of the first toggle linkage is relatively low when said first toggle linkage is operating near its on-center position compared to that which would be transmitted to said toggle linkage if the toggle linkage were operating further away from its on-center position.

6. The switch of claim **3** in which:

a. said spring means comprises a closing spring that discharges during the early stages of a switch-closing operation to accelerate said second contact in a switch-closing direction, and

b. snubbing means is provided for blocking said spring from further discharging at a point substantially ahead of the point at which said contacts engage during a switch-closing operation.

7. The switch of claim **4** in which:

a. said spring means comprises a closing spring that discharges during the early stages of a switch-closing operation to accelerate said second contact in a switch-closing direction, and

b. snubbing means is provided for blocking said spring from further discharging at a point substantially ahead of the point at which said contacts engage during a switch-closing operation.

8. The switch of claim **5** in which:

a. said spring means comprises a closing spring that discharges during the early stages of a switch-closing operation to accelerate said second contact in a switch-closing direction, and

b. snubbing means is provided for blocking said spring from further discharging at a point substantially ahead of the point at which said contacts engage during a switch-closing operation.

9. The switch of claim **1** in which:

a. said magnetic-assist means comprises two side-by-side bars electrically connected in series with said contacts in such a manner that current at any instant flows in opposite directions through said bars to develop a repulsive magnetic force therebetween that drives one of said bars in a switch-closing direction,

b. and said means for transmitting said magnetic force is connected between said one bar and said second contact.

10. In the switch of claim **1**,

a. a second set of contacts comprising a first contact and a second contact that is movable into and out of engagement with said first contact,

b. additional triggering means operable substantially simultaneously with triggering means of claim **1** to cause current to flow between the contacts of said second set while the contacts of said second set are substantially fully separated,

c. means for connecting both sets of contacts in series so that current flows in series therethrough when both said triggering means are operated,

d. the electromagnetic assist means of claim **1** being common to the two sets of contacts and being connected in series with said two sets of contacts to develop responsive to current flow therethrough a second magnetic force acting in a switch-closing direction on the movable contact of said second set of contacts,

e. means corresponding to the force transmitting means of (*d*) of claim **1** for transmitting said second magnetic force to the second contact of said second set,

f. second spring means biasing the second contact of said second set toward closed position when the contacts of said second set are fully separated, and

g. the releasable means of (*f*) of claim **1** also holding the second contact of said second set in its fully-separated position and, upon release, permitting said second spring means to drive said second contact of said second set toward engaged position.

11. The switch of claim **10** in which said magnetic-assist means comprises two side-by-side bars through which current at any instant flows in opposite directions to develop a repulsive effect therebetween that produces said two magnetic forces, one of said force-transmitting means being connected between one of said bars and one of said second contacts, and the other of said force-transmitting means being connected between the other of said bars and the other of said second contacts.

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