Oct. 12, 1965 — E. B. HEFT — 3,211,867

ELECTRIC SWITCHING DEVICE HAVING SEGMENTED NON-WELDING CONTACT ASSEMBLY

Filed June 28, 1963 — 2 Sheets-Sheet 1

FIG. 1.

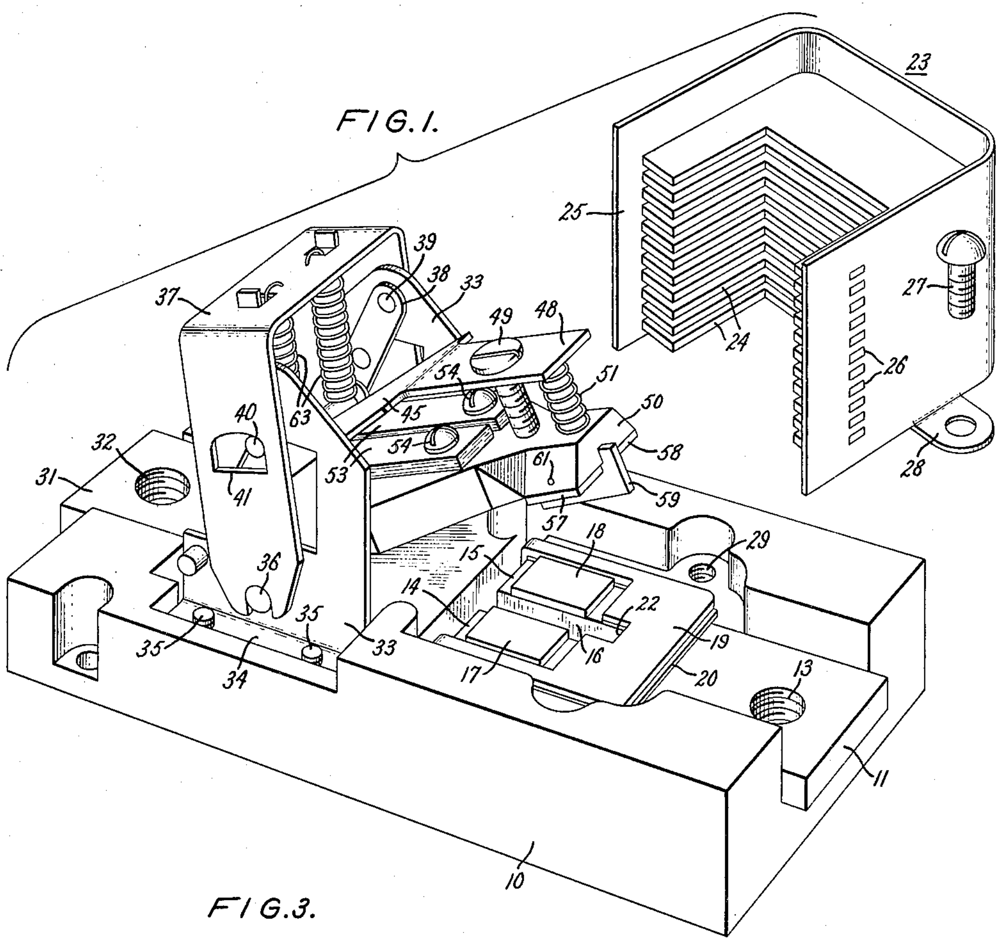


FIG. 3.

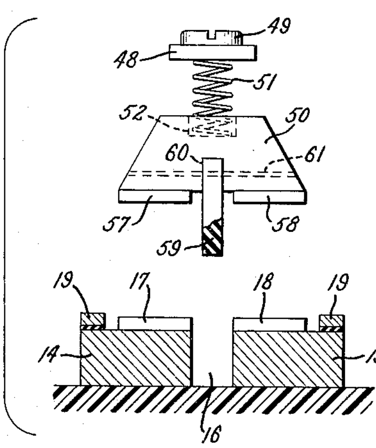
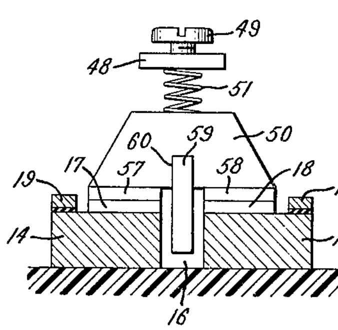


FIG. 4.



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ELECTRIC SWITCHING DEVICE HAVING SEGMENTED NON-WELDING CONTACT ASSEMBLY

Filed June 28, 1963 2 Sheets-Sheet 2

FIG. 2.

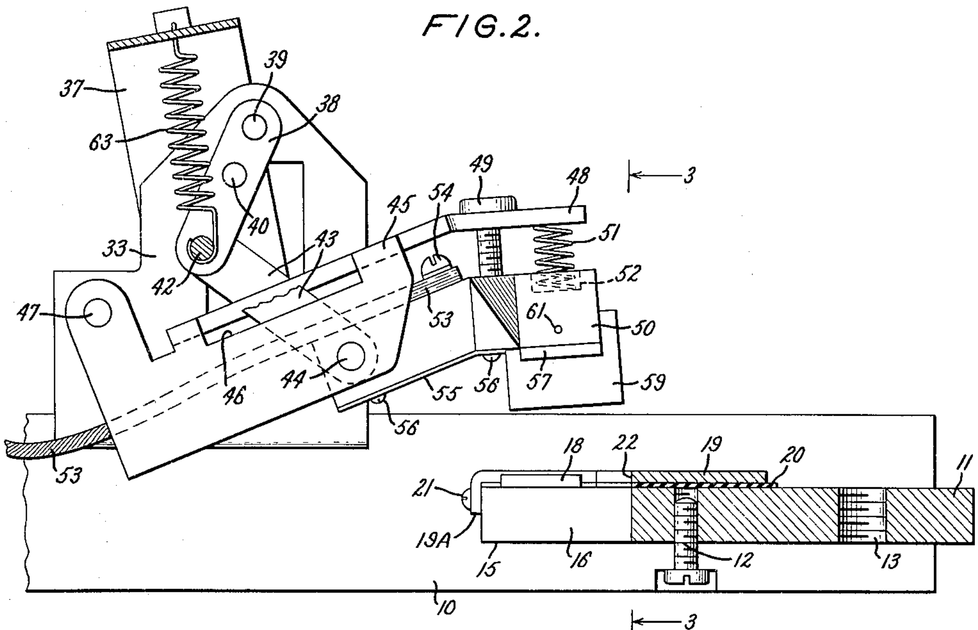


FIG. 5A.

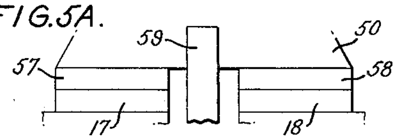


FIG. 5B.

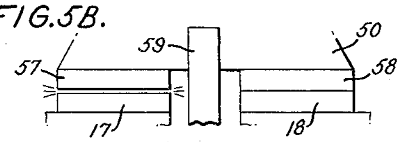


FIG. 5C.

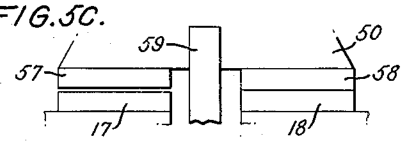


FIG. 5D.

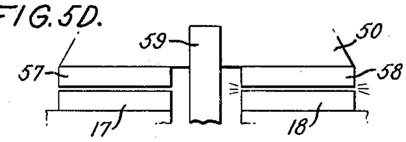


FIG. 5E.

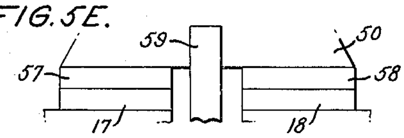


FIG. 5F.

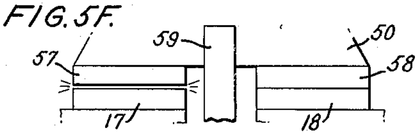
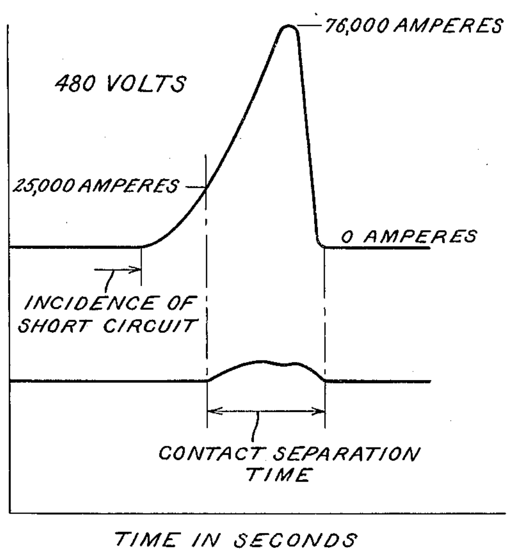


FIG. 6.



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United States Patent Office — 3,211,867 — Patented Oct. 12, 1965

3,211,867

ELECTRIC SWITCHING DEVICE HAVING SEGMENTED NON-WELDING CONTACT ASSEMBLY

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Filed June 28, 1963, Ser. No. 291,367
5 Claims. (Cl. 200—144)

The present invention relates to electric switching devices, and more particularly to electric switching devices having the ability to withstand high electrical short-circuit currents without welding of contacts.

When a short-circuit occurs in a circuit including a switching device and a protective device such as a fuse, a temporary surge of current passes through the circuit during the brief period between the incidence of the short-circuit and the time when the current is interrupted by the fuse. This current may, in devices of the type to be described, be as high as 50,000 to 75,000 amperes (peak). This current must, of course, be carried by all elements in the circuit on the line side of the fault, including the switching device. Although the contacts of the switching device are ordinarily held in the closed position by a relatively strong spring action, the high short-circuit current passing through the contacts has the effect of causing localized heating at the contact interfaces with melting and vaporizing of contact material and subsequent temporary separation of the contacts accompanied by arcing, melting and errosion of contact material. In the case of prior art switches, after the circuit is interrupted by the fuse, and the contacts of the switch reclose, they are often found to have become solidly welded together.

Such contact-welding has been a particular problem with switches of medium to high capacity, such as 400 to 800 or more amperes, using "butt-type" contacts, which switches have become of greatly increased importance in recent years because of their excellent current-interrupting abilities. For example, a switch having a normal current-carrying rating of 400 amperes is commonly required to be able to interrupt currents of 10,000 amperes, and to be able to "withstand" the interruption of short-circuit currents of 50,000 amperes by an associated electrical protective device such as a fuse.

Various attempts have been made in accordance with the prior art to avoid the contact-welding difficulty by preventing the contacts from moving apart at all during such a short-circuit current. Thus switches have been provided including means for moving the contacts to closed circuit position, supplemented by mechanical clamping means for maintaining the contacts in closed circuit position. While such "pressure" switches are relatively successful in avoiding welding of the contacts, such switches require comparatively complicated mechanisms and therefore are relatively large, bulky, and expensive. In addition, such switches suffer from the serious disadvantage that if the switch is accidentally closed on a short-circuit condition, the clamping pressure is not available to hold the contacts in closed circuit position. Special arcing contacts must be therefore provided if the danger of welding, or possible explosion, is to be avoided.

Efforts have also been made to avoid contact welding by utilizing magnetic forces to maintain contacts closed at all times during short-circuit current conditions. While such magnetic means are somewhat helpful in increasing the withstandability level of a given switching device, the improvement obtained by this means is not sufficient to meet the needs created by the rapidly increasing capacities of modern electrical distribution systems.

It is an object of the present invention to provide an electrical switching device which is capable of withstanding high short-circuit currents during the period required for such currents to be interrupted by an electrical protective device without welding of the switch contacts.

It is another object of the invention to provide an electric switching device which is capable of withstanding high short-circuit currents without welding of the switch contacts and which is operable by simple quick-make quick-break type mechanism.

In accordance with the invention, I provide an electric switching device including a bifurcated movable contact member and a bifurcated stationary contact member, and a barrier member extending between the contact bifurcations generally parallel to the plane of movement of the movable contact member to prevent arc gases from one of said contact bifurcations from directly impinging on the other of said contact bifurcations. The movable contact member is, moreover, rigidly mounted so as to permit pivotal movement toward and away from the stationary contacts but to substantially completely prevent any rocking movement transversely to such direction of movement.

In operation, material which is melted and vaporized between one pair of said contact bifurcations, during the period of time an associated electrical protective device is interrupting a short-circuit current, is blown out from between them, thereafter permitting the second pair of contact bifurcations to come together and leaving substantially no pressure acting on the first pair of contact bifurcations, thereby preventing welding between the first pair of contact bifurcations. If a second short-circuit current occurs, material is blown out from between the *second* pair of contact bifurcations, permitting the first pair of contacts to thereafter come together, removing substantially all pressure from and preventing welding of the second pair of contacts.

The invention will be more fully understood from the following detailed description, and its scope will be pointed out in the appended claims.

In the drawings,

FIGURE 1 is a perspective view of an electric switching device incorporating the invention, the arc chute assembly being shown in exploded relation;

FIGURE 2 is an elevational sectional view of the switching device of FIGURE 1;

FIGURE 3 is a fragmentary sectional view of the switching device of FIGURE 2 taken substantially on the line 3—3 of FIGURE 2;

FIGURE 4 is a sectional view similar to FIGURE 3 but showing the contacts in closed condition;

FIGURES 5A through 5F are fragmentary views similar to FIGURE 4, showing changes in the contact assembly after being subjected to a series of short-circuit currents, and

FIGURE 6 is a reproduction of a portion of an oscillogram taken during a test of the invention.

Referring to FIGURE 1, the invention is shown as incorporated in an electric switching device including an insulating base **10** having a line terminal strap **11** mounted thereon by suitable means, such as by means of mounting screw **12** (see FIGURE 2). The line terminal strap **11** includes a tapped hole **13** for the purpose of connecting a suitable line conductor (not shown). The inner end of the terminal strap **11** is formed to provide bifurcated portions **14** and **15** with a cut or recess therebetween **16**. A pair of stationary contact portions **17** and **18** are mounted on the bifurcated portions **14** and **15** of the line terminal strap **11** respectively.

A generally U-shaped arc runner plate **19** is also mounted on the inner end of the line terminal strap **11**, being insulated therefrom throughout its major flat portion by a sheet of fiber type insulating material **20**. The arc runner plate **19** has its end portions **19A** bent-over and connected to the line terminal strap **11** by suitable means such as by screws **21** (see FIGURE 2). The arc runner plate **19** also has its center portion notched or cut-away as at **22**. The construction of the arc runner plate **19** is substantially as shown and described in prior application Serial No. 209,418, filed July 12, 1962, by K. W. Klein et al., now Patent No. 3,118,036, issued January 14, 1964, and assigned to the same assignee as the present invention.

Suitable arc cooling and extinguishing means may be used with the invention, such for example as indicated generally at **23** in FIGURE 1 and comprising a series of generally U-shaped magnetic metallic plates **24** assembled in spaced vertically aligned relation by means of a generally U-shaped fiber insulating sheet **25**, the plates **24** having lug portions **26** projecting through the fiber piece **25**. The arc chute assembly shown in FIGURE 1 is adapted to be held in mounted relation on the base **10** by means of screws **27** extending through lug portions **28** of the fiber piece **25** and into corresponding holes **29** of the base **10**.

At the end of the insulating base **10** opposite from the line strap **11** is mounted a load connecting strap **31** by suitable means, not shown, and including a tapped hole **32** for receiving a suitable load connector, not shown.

A contact operating mechanism is mounted on the base **10** between the line strap **11** and the load strap **31**, and includes a pair of mechanism side-frame pieces **33** having bent-over edge portions **34** rigidly mounted to the base **10** by suitable means such as by screws **35**. The side-frames **33** each includes a pivot pin **36** serving to pivotally support a generally inverted U-shaped handle member **37**.

The handle member **37** is adapted to be rocked about the pivot pins **36** to open and close the switch contacts. It will be understood that suitable manually operable means may be provided for operating the member **37**, and also that two or more of the switch assemblies illustrated may be and commonly are ganged together for common operation, such as by rigidly attaching an insulating cross-piece to the handle support member **37**. Since such operating means forms no part of the present invention, however, they have been omitted for reasons of simplification and clarity.

Each of the side-frames **33** also supports an upper toggle link **38** on a suitable pivot pin **39**. Each of the upper toggle links **38** includes a projecting pin **40** which extends into a window or opening **41** in the side portions of the handle member **37**, for the purpose of positively initiating toggle-straightening and toggle-collapsing movements. The upper toggle links **38** are connected by means of a toggle knee pin **42** (see FIGURE 2) to lower toggle links **43**, which in turn are pivotally connected by means of pivot pin **44** to a generally channel-shaped rigid contact arm **45**. The bight portion of the contact arm **45** has a pair of elongated slots **46** cut therein, through which the links **43** respectively extend. The side portions of the contact arm **45** are extended and are pivotally supported on the side-frames **33** by means of pivot pin **47**. The bight portion of the contact arm **45** is extended forwardly at **48**, and carries a contact-depression adjusting screw **49**, which threadedly engages the movable contact member **50** which is also pivotally supported on the pivot pin **44**.

The movable contact member **50** is constantly biased away from the contact arm extension **48** by means of a compression spring **51**, which has one end abutting the extension **48** and which has its other end extending into a recess **52** in the contact member **50**.

For the purpose of flexibly connecting the movable contact member **50** to the load terminal strap **31**, a pair of flexible conductors **53** are provided, which are connected at one end to the contact member **50** by suitable means such as by screws **54**. The movable contact member **50** has a sheet of insulating material **55** rigidly attached to the underside thereof by suitable means such as by rivets **56** to shield it from arc gases generated between the contacts.

The movable contact member **50** carries a pair of spaced apart movable contact portions **57** and **58** which are separated by an insulating barrier comprising insulating member **59** (see FIGURE 3). The insulating barrier **59** is retained in a slot **60** in the movable contact member **50** by means of a pin **61** which is pushed into a transverse hole in the movable contact member **60**, in tightly-fitting relation.

The operating handle **37** is connected by means of a pair of operating springs **63** to the knee pins **42** of the toggle links **38–43**.

Movement of the operating handle **37** about its pivotal support causes the operating springs **63** to move across the center line of the pivot pins **39, 42**, until the toggle linkage is snapped from the collapsed condition as shown in FIGURES 1 and 2 to straightened position, moving the contact arm **45** clockwise about its pivotal support **47** and bringing the movable contacts **57** and **58** into contact with the stationary contacts **17, 18**, respectively, and causing the barrier **59** to enter the space **16** between the bifurcations **14** and **15** of the line terminal strap **11**.

The parts are shown in the closed condition, for example, in FIGURE 4. The switching device may therefore be operated manually or by other suitable means to open and close a circuit. The illustrated embodiment, for example, is suitable for carrying 400 amperes normally at 600 volts, and can be used to interrupt currents up to 10,000 amperes.

When the switching device is in the closed-circuit position as shown for example in FIGURE 4, and is subjected to high short-circuit currents, in the neighborhood, for example, of 50,000 to over 75,000 amperes, the device remains closed, and is undamaged by the short-circuit current, and the contacts do not become welded together. The operation of the device, by observations of actual tests, is as follows, reference being had in this connection to the series of FIGURES 5A through 5F.

As initially manufactured, the contact portions **57** and **58** are made of equal height, as are the contact portions **17** and **18**. The pivotal support (pivot pin **44**) for the movable contact member **50** is, furthermore, made to extend as nearly parallel as possible to the meeting contact surfaces. Contrary to common expectation, however, the pairs of contact portions **17–57** and **18–58** do not make equally good electrical contact. Instead, one such pair of contact portions will make good contact and will carry substantially all of the current, and the other pair of contact portions will make poor contact and will carry substantially none of the current.

When the contact assembly illustrated in FIGURE 5A is first subjected to a short-circuit current of high magnitude, therefore, material is heated, melted, vaporized, and blown out from between the two contact portions which happen to be carrying the most current, such for example as from between contact portions **17** and **57**. This action removes some of the contact material from these two contacts, with the result that when the short-circuit current is interrupted by a series-connected protective device, such as a fuse (not shown), and the contact parts cool, a small space will be found to exist between the formerly meeting contact portions **17–57**. The other pair of contact portions, that is, **18–58**, will then be found to be supporting virtually all of the contact pressure. It will then be found that if a succeeding short-circuit is experienced, material will be blown out from between the contact portions **18–58**, as indicated in FIGURE 5D, removing material from these two contact portions, the contact assembly, after removal of the short-circuit then assuming the condition illustrated in FIGURE 5E. A third short-circuit would then cause melting and blasting out of additional material from the contact portions **17–57**, as indicated in FIGURE 5F.

Successive short-circuits, in other words, cause melting and blasting out of material from between the contact portions, first of one pair, and then of the other, in alternating fashion.

While the phenomenon taking place during electrical transients of extremely short duration and high magnitude, such as that involved in the subject invention, are extremely difficult to analyze and cannot always be accurately or completely understood, the following is what is believed to be taking place in the operation of the subject invention.

Although the contact surfaces initially, as indicated in FIGURE 5A are as flat as conventional manufacturing procedures permit, and appear to be perfectly flat by all conventional measuring techniques, it is believed that the surfaces actually contain many minute irregularities or high and low spots. When the contacts are brought to closed position as indicated in FIGURE 5A, therefore, some one pair of meeting points of the two contact pairs will be higher relatively than any other pair of points on either of the two pairs of contacts. Most of the contact pressure will therefore be absorbed at these points, and the resistance at the contact interface will be lowest at this point. Most of the current will therefore flow between the contacts through this particular contact point. When a short-circuit occurs, the rapidly rising current passing through the localized point of good contact causes heating of the contact metal at these points. This heating is believed to be enough to melt the contact metal at these points and also to boil it, transforming it to an ionized gas. Current conduction, however, continues between the contacts at this point by means of an arc carried through the ionized gas. At the same time, the gases created by the vaporizing metal expand rapidly, exerting a high force on the two contacts, forcing them apart. Once the arc is created in the ionized gas, it does not remain localized at the particular point in which it was first created, but moves rapidly across the surface of the contact at which it occurs, in a random manner, giving the impression that the arc exists between the entire confronting surfaces of the two contacts. It is believed, based on oscillograms taken during tests, that the pressure of the gases generated at this time are sufficient to hold both pairs of contacts in the open circuit position, thereby preventing the other pair of contacts from by-passing the arc. It has been observed, for example, that the movable contact arm is thrown upwardly violently, with a force sufficient, at times, to break the insulating base **10** on which the parts are mounted.

Once the short-circuit current has been extinguished by the action of the fuse which is in series with the switch, the contact pressure spring **51** forces the movable contact member **50** back to close circuit position. Because a substantial amount of material has been blasted away from between the contact portions **17–57**, however, these contacts do not touch each other, but instead the force of the spring **51** is taken by the contact portions **18–58**. Actual spacing between the contact portions **17–57**, following such a short-circuit test, has been measured at almost 1/32 of an inch. In this connection, it is pointed out that special care is taken to see that the contact member **50** is well supported against rocking or twisting movement. For this reason, the pin **47** is made to fit as closely as possible in its bearings, and the side-frames **33**, at the points where they support the ends of the pin **47**, are widely spaced compared to the spacing between the contact portions **57–58** and **17–18**. In other words, the movable contacts **57, 58** are constrained to move simultaneously along paths of movement extending parallel to each other at all times.

When a second short-circuit occurs, therefore, a similar sequence of events takes place involving the other pair of contact portions, which again are blown apart and have a substantial portion of the contact material thereof melted and vaporized and blown out from between the contacts. The amount of material which is vaporized and blown out from between the contacts is believed to be a function of the let-through energy which must be withstood. This, in turn, depends upon the electrical circuit and on the type and rating of fuse which performs the interruption. In a given application, in other words, with voltage and available short-circuit current constant, the let-through energy will be nearly constant in repeated interruptions using the same type of fuse.

Since the material removed from the contact portions **18–58** in the second short-circuit interruption can be expected to be approximately equal to the amount of the material removed from the contact portions **17–57** during the first interruption, following extinction of the current the contact member **50** is again urged toward closed circuit position by the spring **51**, bringing the contact portions **57** and **58**, to all appearances, both in contact with the stationary contact portions **17–18**.

This condition resembles the condition which existed at the begining of the test, that is, the condition illustrated in FIGURE 5A, and it might be expected that conductivity through one pair of the contacts rather than the other would be better, by a random factor, in the same manner as with the original switches, but this has been found not to be the case. Instead, it has been found that the pair of contact portions, such as **17–57**, which did *not* experience the most recent short-circuit current will at this time provide the better contact, and therefore will experience the short-circuit current and blasting out of further contact material. This is believed to be because of the fact that when the contact portions **18–58** were subjected to a short-circuit current, and the contacts immediately reclosed by the action of the contact pressure spring **51**, the contact materials at the meeting faces of the contacts **18–58** is still relatively hot and therefore somewhat plastic. The meeting of the contacts therefore would permit some flattening of any major projections, so that most of the contact pressure would then be absorbed by the other pair of contacts. The contacts **17–57**, it will be observed however, were allowed to return to their cool or normal temperature condition without being pressed together at all. This, it is believed, permits the formation of surface irregularities on the contacts **17–57** which then cause it to provide better contact than the contacts **18–58** after the succeeding short-circuit shot.

As shown diagrammatically in FIGURE 6, in a particular embodiment which was tested in connection with an electrical power sub-station capable of delivering 54,000 amperes RMS symmetrical at 480 volts, single-phase, at 15% power factor, the contacts opened when the current reached an instantaneous value of 25,000 amperes and remained open through the peak current of 76,000 amperes, until the current was reduced to zero by the action of fuses connected electrically in series with the switch. No welding of the contacts occurred on three repeated shots at this value.

Conventional electrical switches of construction similar to that tested above, were found unable to withstand short-circuit currents above 30,000 amperes peak instantaneous value on this same circuit. In terms of the amount of energy which the switch is capable of withstanding, conventional switches of this rating (480 volts, 400 amperes) were capable of withstanding only $2\times10^6 I^2t$, while switches of the same rating incorporating the invention successfully withstood energy equal to $23\times10^6 I^2t$.

The barrier **59** extending between the two movable contacts is preferably constructed of vulcanized fiber, because of the desirable physical strength and non-tracking characteristics of this material. Other insulating materials may, however, be used, providing they have the required physical strength to resist destruction from the pressure of the gas at one side thereof, are non-tracking, and sufficiently heat resistant.

The contact materials used in the illustrated embodiment were as follows: the stationary contacts, 90% silver and 10% cadmium oxide; the movable contacts, 65% tungsten and 35% silver.

While the invention has been shown only in certain particular embodiments, it will be readily apparent that many modifications thereof may readily be made. It is therefore intended by the appended claims to cover all such modifications as fall within the true spirit and scope of the invention.

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

1. An electric switching device comprising:
(a) a pair of discrete movable contacts;
(b) a pair of discrete stationary contacts;
(c) means connecting said movable contacts electrically in common;
(d) means connecting said stationary contacts electrically in common;
(e) means for moving said movable contacts in reciprocating fashion between a closed circuit position in which at least one of said movable contacts is in engagement with a corresponding one of said stationary contacts and an open circuit position in which said movable contacts are spaced away from said stationary contacts;
(f) means rigidly connecting said movable contacts to each other and preventing movement of said movable contacts relative to each other;
(g) means rigidly connecting said stationary contacts to each other and preventing movement of said stationary contacts relative to each other;
said means for moving said movable contacts between said closed circuit position and said open circuit position comprising means constraining said contacts to simultaneous movement along paths extending parallel to each other at all times;
(h) barrier means extending between said pair of movable contacts and between said pair of stationary contacts when said movable contacts are in said closed circuit position and adjacent said closed circuit position to prevent the passage of arc products directly from one pair of contacts to the other when said stationary contacts are in said closed circuit position and adjacent said closed circuit position.

2. An electric switching device comprising:
(a) a movable contact member having at least two discrete spaced contact portions;
(b) a stationary contact member having at least two discrete spaced contact portions for cooperation with said contact portions of said movable contact member;
(c) means rigidly connecting said spaced contact portions of said movable contact member to each other and preventing movement of said contact portions relative to each other;
(d) means rigidly connecting said spaced contact portions of said stationary contact member to each other and preventing movement of said contact portions relative to each other;
(e) means for moving said movable contact member in reciprocating fashion between a closed circuit position in which at least one of said spaced contact portions of said movable contact member is in engagement with a corresponding one of said spaced contact portions of said stationary contact member and an open circuit position in which said contact portions of said movable contact member are out of contact with said contact portions of said stationary contact member, said means comprising means constraining said contact portions of said movable contact member to simultaneous movement along paths extending parallel to each other at all times;
(f) barrier means extending between said contact portions of said movable contact member and between said contact portions of said stationary contact member when said contact portions of said movable contact member are in contact with said contact portions of said stationary contact member, for preventing arc products created between one of said movable contact portions and a corresponding one of said stationary contact portions from impinging directly upon the other of said movable contact portions and on the other of said stationary contact portions.

3. An electric switching device comprising:
(a) a movable contact member having at least two discrete spaced contact portions rigidly mounted thereon;
(b) a stationary contact member having at least two discrete spaced contact portions rigidly mounted thereon for cooperation with said contact portions of said movable contact member;
(c) said movable contact member having sufficient rigidity to prevent relative movement between said contact portions mounted thereon;
(d) means preventing relative movement between said stationary contact portions;
(e) barrier means extending between said contact portions of said movable contact member and between said contact portions of said stationary contact member when said movable contact portions are in engagement with said stationary contact portions, for preventing arc products created between one of said movable contact portions and the corresponding one of said stationary contact portions from impinging directly upon the other of said movable contact portions and on the other of said stationary contact portions;
(f) means for moving said movable contact member between open and closed circuit positions, said moving means comprising means for moving said spaced contact portions of said movable contact member simultaneously along paths of movement extending parallel to each other at all times.

4. An electric switching device comprising:
(a) a movable contact member having at least two discrete spaced contact portions rigidly carried thereby;
(b) a stationary contact member having at least two discrete spaced contact portions rigidly carried thereby for cooperation with said contact portions of said movable contact member;
(c) means preventing relative movement of said contact portions carried by said movable contact member;
(d) means preventing relative movement of said contact portions carried by said stationary contact member;
(e) a barrier carried by said movable contact member and extending between said contact portions carried by said movable contact member, and
(f) said stationary contact member having a recess between said contact portions carried thereby, said recess being adapted to receive at least a portion of said barrier when said movable contact portions are in engagement with said stationary contact portions to prevent arc products created between one of said movable contact portions and a corresponding one of said stationary contact portions from impinging directly upon the other of said movable contact portions and on the other of said stationary contact portions;
(g) means for moving said movable contact member between open and closed circuit positions, said moving means comprising means for constraining said spaced contact portions of said movable contact member for simultaneous movement along paths of movement extending parallel to each other at all times.

5. An electric switching device comprising:
(a) a support;
(b) a movable contact arm, means pivotally supporting

said movable contact arm pivotally supported on said support;

(c) a metallic movable contact member carried by said contact arm;

(d) a pair of discrete spaced movable contact portions, said movable contact portions on said contact member in side-by-side alignment in a direction transversely of the length of said contact arm;

(e) a pair of spaced discrete stationary contact members rigidly mounted on said support in a position to be engaged by said movable contact portions in at least one position of said contact arm;

(f) a recess in said movable contact member extending inwardly between said contact portions carried by said contact member;

(g) a space between said stationary contact portions;

(h) said space between said stationary contact portions extending in contiguous relation to said recess in said movable contact member when said movable contact member is in closed circuit position, and

(i) insulating barrier means extending at least partly into said recess of said contact member and at least partly into said space between said stationary contact portions when said movable contact member is in said closed circuit position for preventing arc products created between one of said movable contact portions and a corresponding one of said stationary contact portions from impinging directly upon the other of said movable contact portions and on the other of said stationary contact portions, said means pivotally supporting said movable contact arm and on said support and said means mounting said movable contact portions on said movable contact member constraining said movable contact portions to move simultaneously along paths of movement extending parallel to each other at all times.

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