

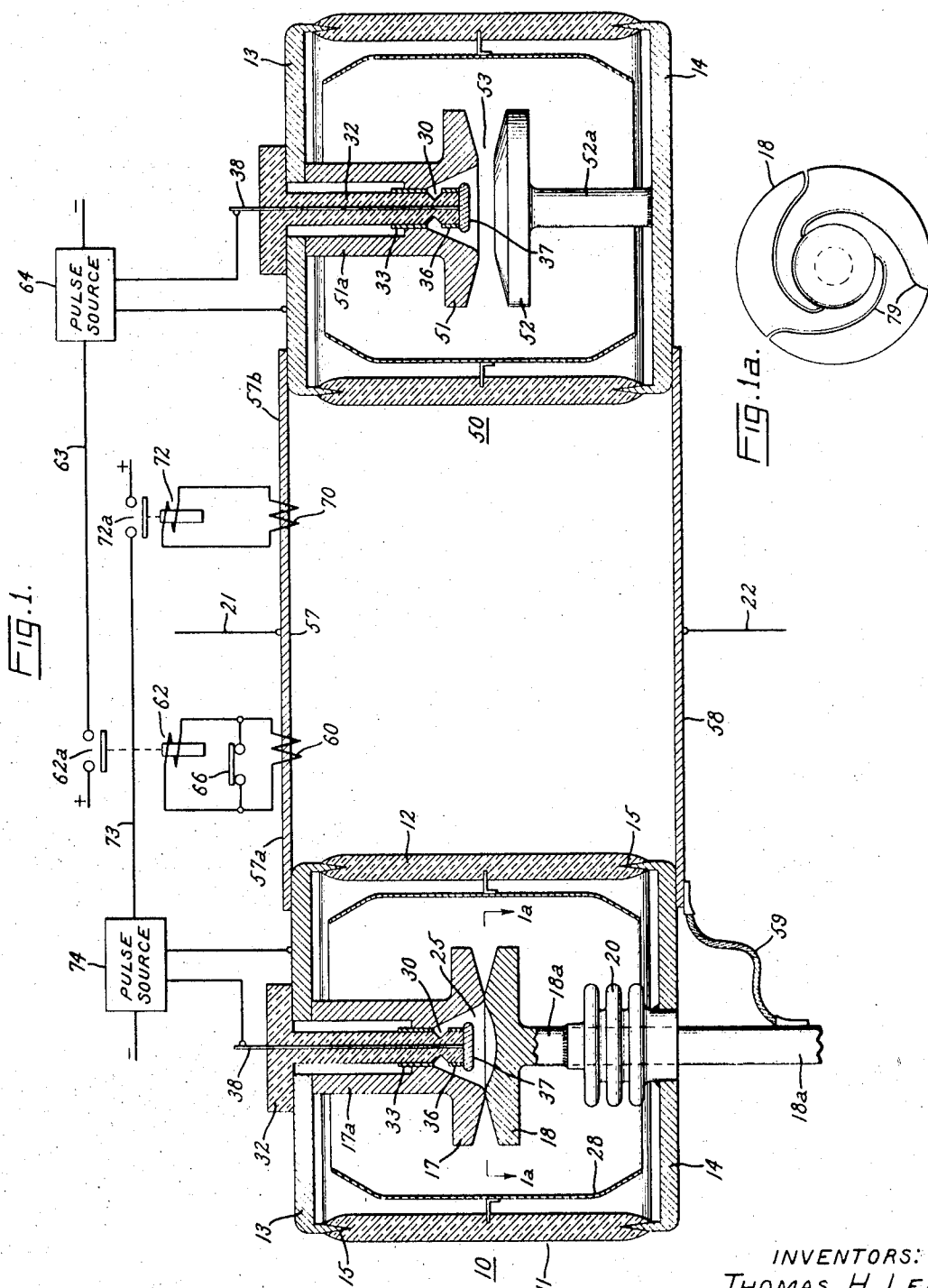
Sept. 23, 1969

T. H. LEE ETAL
VACUUM-TYPE CIRCUIT BREAKER HAVING PARALLEL
TRIGGERED-TYPE CIRCUIT INTERRUPTERS

3,469,048

Filed July 1, 1966

3 Sheets-Sheet 1



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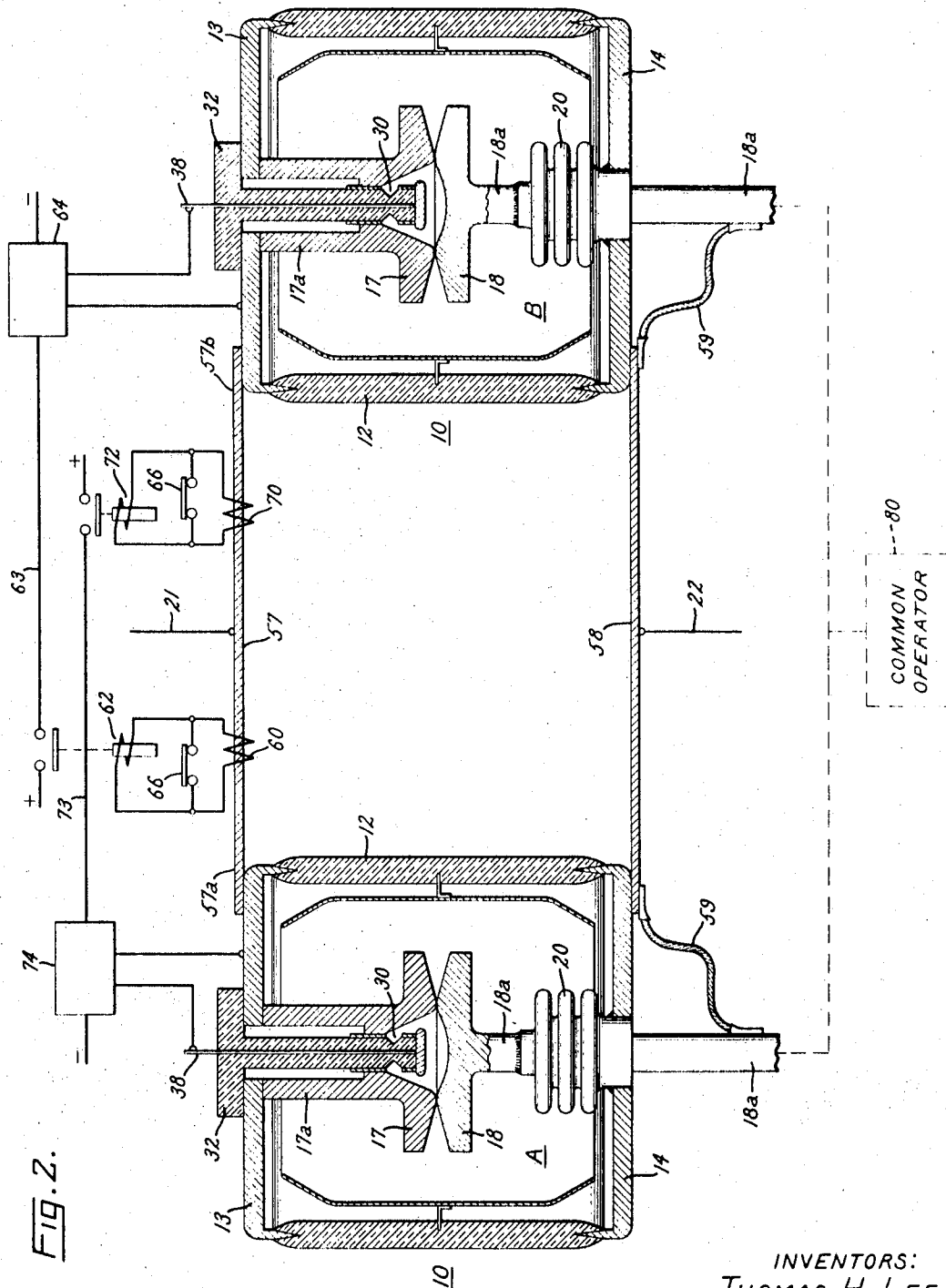
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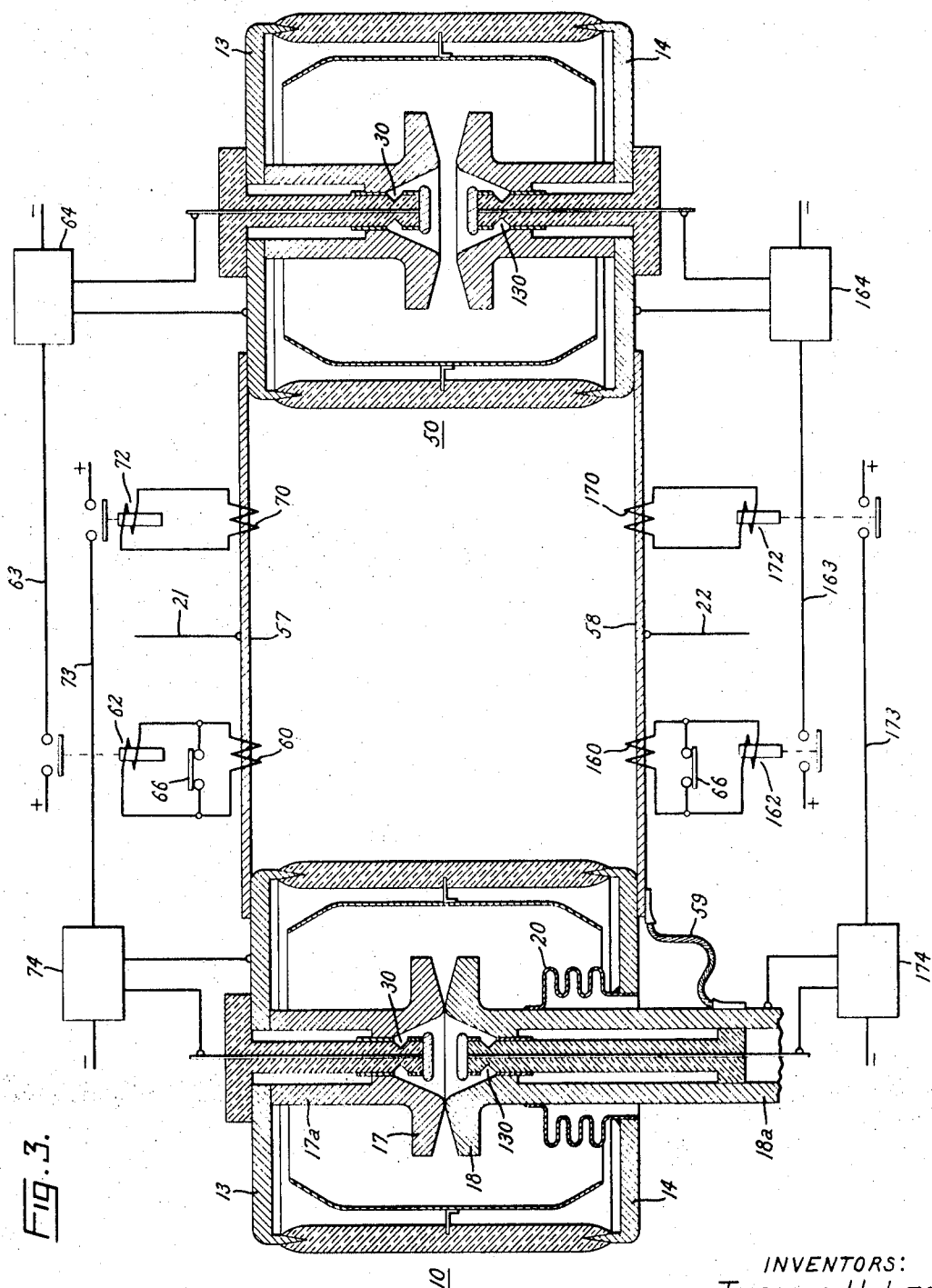


FIG. 3.

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VACUUM-TYPE CIRCUIT BREAKER HAVING PARALLEL TRIGGERED-TYPE CIRCUIT INTERRUPTERS

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11 Claims

ABSTRACT OF THE DISCLOSURE

Discloses a vacuum circuit breaker that comprises a pair of triggered vacuum-type circuit interrupters electrically connected in parallel. During interruption, coexisting arcs are developed in the two parallel vacuum interrupters, and the total current is divided between the parallel coexisting arcs. When the current through the arc in one of interrupters exceeds a predetermined value, the other interrupter, if it is not then conducting, is triggered into conduction to establish an arc therein through which a portion of the total current flows.

This invention relates to a vacuum-type electric circuit breaker and, more particularly, relates to a circuit breaker of this type which comprises a plurality of vacuum-type interrupting devices electrically connected in parallel.

It has heretofore been proposed that liquid or gas-type circuit interrupters be connected in parallel in order to increase the amount of current that can be interrupted. The general objective of such proposals has been to distribute the total interrupting current between the parallel-connected interrupters, thereby reducing the interrupting duty imposed on each interrupter. Heretofore, this general objective has been found extremely difficult to attain, and this has discouraged the use of parallel-connected interrupters.

One of the difficulties encountered has been that of obtaining a substantially equal distribution of current between the interrupters. In this regard, assume that each of the parallel-connected interrupters comprises a pair of relatively movable contacts which are separable for the purpose of drawing an arc therebetween. Assume further than an effort is made to separate the contacts substantially simultaneously when opening is desired. Hardly ever, however, will such separation occur precisely simultaneously. The usual result of this imperfect synchronization is that the last contacts to part will be carrying all of the current when they part. This can result in an arc being established only at the last contacts to part, thus concentrating the entire interrupting duty on these contacts.

It has been proposed to connect an inductance in series with each interrupter in order to encourage the establishment of arcs at all the interrupters and in order to force the arcs to evenly share the current, but such inductances to be effective must be relatively large. The presence of such large inductances not only materially increases the cost of the circuit breaker but also makes more severe the recovery voltage appearing across the contacts of the breaker at a current zero following arcing. The increased severity of the recovery voltage transient makes it more difficult to interrupt the circuit.

Another difficulty that has been encountered is that imperfect synchronization of the contact-separating operations may result in some of the contacts opening just prior to current zero and others opening just after current zero. Even if an arc can be established before current

zero at the first set of contacts to open, this arc will not usually reignite after current zero. As a result, all the current that flows after current zero will flow through the contacts that are then closed and when these latter contacts part to establish a new arc, all the current flows through this new arc.

An object of the present invention is to distribute the interrupting duty under high current conditions between parallel-connected interrupters without requiring large inductances in circuit with the interrupters.

Another object is to distribute any high current interrupting duty imposed after a current zero between a pair of parallel-connected interrupters, even under those conditions when contact-separation or arcing has taken place at only one of the interrupters prior to the current zero.

Still another object is to obviate the need for mechanically operating all of the parallel-connected interrupters in synchronism.

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

FIG. 1 is a schematic showing of a circuit breaker embodying one form of the present invention.

FIG. 1a is a sectional view along the line 1a-1a of FIG. 1.

FIG. 2 is a schematic showing of a modified form of the invention.

FIG. 3 is a schematic showing of another modified form of the invention.

Referring now to FIG. 1, there is shown a vacuum-type circuit interrupter 10 comprising a sealed envelope 11 that is evacuated to a pressure of 10^{-4} mm. of mercury or lower. The envelope 11 comprises a casing 12 of insulating material and a pair of metallic end caps 13 and 14 joined in vacuum-tight relationship to the respective opposite ends of the casing 12 by suitable seals 15.

Located within the evacuated envelope 11 is a pair of relatively movable contacts 17 and 18, preferably of a disc shape. The upper contact 17 is a stationary contact which is supported on the upper end cap 13 by means of a tubular supporting rod 17a of conductive material. The lower contact 18 is a movable contact which is joined to and carried by an elongated conductive operating rod 18a that projects through an opening in the lower end cap 14. A flexible metallic bellows 20 is provided about the operating rod 18a to permit vertical movement thereof without impairing the vacuum inside envelope 11. This bellows 20 is secured by suitable seals at its respective opposite ends to the end cap 14 and the operating rod 18a.

The power circuit through the interrupter 10 extends between power lines 21 and 22, which are respectively connected to the end cap 13 and movable contact rod 18a. The connection between power line 21 and end cap 13 is through a conductive bar 57, and the connection between power line 22 and the movable contact rod 18a is through flexible conductive braid 59 and a conductive bar 58. The braid is connected between contact rod 18a and bar 58.

Interruption of this power circuit is effected by driving the movable contact 18 downwardly by suitable operating means (not shown) located at the lower end of contact rod 18a. This separates the contacts 17 and 18 and establishes an arc therebetween. Assuming the circuit is an alternating-current circuit, this arc persists until about the time of a natural current zero, at which time it vanishes and is normally prevented from reigniting by the high dielectric strength of the vacuum inside envelope 11. For condensing the metal vapors liberated by the arc from the contacts, a conventional metallic vapor-condensing shield 28 is provided. This shield 28 surrounds

the contacts, is spaced therefrom, and is preferably electrically isolated from the contacts.

Under certain conditions (soon to be described), we wish to cause the arc between contacts 17 and 18 to reignite following the first natural current zero and to carry current until the next natural current zero. For this purpose, we incorporate a trigger gap 30 in the vacuum interrupter 10.

This trigger gap 30, which is located within a centrally disposed recess 25 in the stationary contact 17 is preferably constructed in substantially the same manner as disclosed and claimed in U.S. Patent 3,087,092, Lafferty, assigned to the assignee of the present invention. Accordingly, it comprises a cylindrical ceramic support 32 located within recess 25 and two thin layers 33 and 36 of metal bonded to the external surface of the ceramic support in spaced-apart relationship along the length of the support. These two layers of metal constitute the electrodes of the trigger gap 30. They are separated by a V-shaped groove that extends about the circumference of the ceramic support and has its walls defined by the ceramic material itself. One of the trigger electrodes 33 is electrically connected to the main electrode 17. The other trigger electrode 36 is normally isolated from the main electrode 17.

These layers 33 and 36 are formed of a metal such as titanium, which is a good getter for active gases such as hydrogen and which is capable of absorbing a large quantity thereof. In a preferred form of the invention, each of these two layers of titanium is charged with a large quantity of hydrogen in the manner explained in the aforesaid Lafferty patent.

As is well known, the lines of field distribution at the interface between a metal and a ceramic body in intimate contact are highly favorable to a breakdown at such an interface. Accordingly, a relatively low voltage applied across the trigger gap can initiate a spark-over from one of these interfaces across the trigger gap.

When the trigger gap 30 sparks over, the resulting arc at the trigger gap liberates hydrogen gas from the electrodes 33, 36. This hydrogen gas is ionized by the arc, and the ionized hydrogen is rapidly injected into the main gap, thus drastically reducing its dielectric strength and causing it to arc over in response to the voltage then prevailing between the contacts 17, 18.

For enabling a voltage to be applied across the trigger gap, a conductive lead 38 is provided extending through a passageway in the ceramic support. At its inner end, this lead 38 is brazed to a metal cap 37 which is in electrical contact with trigger electrode 36. The metal cap 37 is hermetically sealed to the inner end of ceramic support 32 by a conventional metal-to-ceramic seal so as to maintain the hermetic seal of the envelope.

To relieve the interrupter 10 of some of the interrupting duty accompanying high-current interruptions, we provide an auxiliary vacuum-type circuit interrupter 50 in parallel with the main interrupter 10. This circuit interrupter 50 is a triggered vacuum gap device constructed in substantially the same manner as disclosed and claimed in the aforesaid Lafferty patent. This circuit interrupter 50 is constructed in essentially the same manner as the circuit interrupter 10 except that it has electrodes 51 and 52 which are fixed with respect to each other to define a primary gap 53 therebetween. These electrodes 51 and 52 are of substantially the same configuration as the contacts 17 and 18. Electrodes 51 and 52 are mounted on conductive rods 51a and 52a which are electrically and mechanically connected to the opposite end caps 13 and 14, respectively. The trigger gap 30 of the interrupter 50 is substantially the same as the trigger gap 30 of the interrupter 10, and corresponding reference numerals have therefore been used to designate corresponding parts of the trigger gap. The parallel connection between the interrupters 10 and 50 is provided by suitable means schematically shown in FIG. 1 as com-

prising the conductive bars 57 and 58, which are electrically and mechanically connected between the respective adjacent ends of the two interrupters. Flexible metallic braid 59 is provided for electrically connecting the lower bar 58 and movable contact rod 18a.

In a preferred form of the invention, we allow the triggered vacuum gap 50 to remain in its normally-nonconductive state during low current interruptions. The interrupter 10 alone is capable of easily handling such interruptions and does not need the assistance of the triggered vacuum gap.

For high current interruptions, however, we trigger the normally-nonconductive triggered vacuum gap 50 into conduction when the current through interrupter 10 reaches a predetermined value. This can be done by any suitable current-responsive triggering means. In the illustrated form of our invention, we show a current transformer comprising a secondary winding 60 which is coupled to the portion 57a of bar 57 leading to interrupter 10. An overcurrent relay 62 is connected across the current transformer winding 60. When interrupter 10 is closed, the coil of the relay 62 is effectively shorted out by a normally-closed switch 66 suitably controlled by the operating means (not shown) for interrupter 10. When operation of interrupter 10 is initiated, the switch 66 is opened to remove the shunt from around the relay coil, thereafter allowing the relay 62 to be operated in accordance with the magnitude of the current through interrupter 10.

When the instantaneous current through conductor 57a reaches a predetermined value, sufficient current flows through the coil of relay 62 to cause it to operate and close its contact 62a. This completes a turn-on circuit 63 for a pulse source 64. Pulse source 64 responds by delivering a suitable pulse to the trigger 30 of the triggered vacuum gap device 50. This pulse sparks over the trigger gap 30, thereby quickly initiating an arc across the primary gap 53 of the triggered vacuum gap device 50. This, of course, provides an arcing current path through the vacuum device 50 that is in parallel with the arcing current path through the interrupter 10.

In a liquid or gas interrupter, much more than the mere presence of parallel arcing paths is needed to assure a substantially even distribution of current between the two paths. This is the case because in such interrupters there is an inverse, or negative, relationship between arcing current and arc voltage. If one interrupter is carrying a higher current than the other, its arc voltage will tend to be lower. This tends to cause more current to flow through the higher current arcing path, tending to further reduce its arc voltage, thereby causing still more current to flow therethrough. Thus, with such interrupters, unequal current distribution tends to produce an unstable or runaway condition which leads to even further inequalities. For counteracting this unstable condition, relatively high inductances can be connected in series with respective arcing paths, but such inductances are expensive and introduce other problems, some of which are mentioned hereinabove.

The above-described instability is not present when the parallel interrupters are vacuum-type interrupters carrying high arcing current. This is the case because high current vacuum arcs exhibit a positive arc-voltage-to-current relationship, as contrasted to the negative relationship present in other type interrupters. Thus, if the current through one vacuum arc begins to exceed the current through the parallel vacuum arc, a higher arc voltage is developed by the higher current arc, which tends to equalize the currents through the parallel arcs. This relationship permits us to dispense with the large inductances heretofore necessary when interrupters were connected in parallel. A small amount of inductance, however, can still be used to advantage in certain applications of our invention.

Below a certain current level, the vacuum arc does not exhibit the above-described position arc-voltage-to-current relationship. In this low current range, the arc-voltage remains substantially constant for all currents. Thus, in this low current range, the above described self-equalizing effect is not present to any substantial extent. But this is of no great importance in our interrupting arrangement, since the equal distribution of low currents is not crucial in view of a single interrupter's ability to easily handle low currents by itself.

To provide for a substantially equal distribution of high currents between the two vacuum-type interrupting devices 10 and 50, it is desirable that the two devices 10 and 50 be of such designs that they develop approximately the same arc voltage for a given instantaneous current. At high currents, the amount of arc voltage that will be developed for a given current depends primarily upon the geometry of the electrodes or contacts and, to a minor extent, upon the material used for the electrodes and contacts. Accordingly, in a preferred form of our invention, our electrodes 51, 52 are of substantially the same configuration and size as the contacts 17, 18 and are of similar non-refractory materials. For example, in a preferred embodiment, both the contacts 17, 18 and the electrodes 51, 52 are provided with generally spiral-shaped slots of the type shown and claimed in U.S. Patent 2,949,520, Schneider, assigned to the assignee of the present invention. These slots are shown at 79 in FIG. 1a and are for the purpose of rotating the arc to assist in high current interruption. Similar slots are present in both contacts 17 and 18 and both electrodes 51 and 52. In a preferred form of the invention, the contacts 17, 18 and the electrodes 51, 52 are all made of copper, but the contacts 17, 18 contains a small amount of bismuth in their contact-making regions to inhibit contact-welding.

If the geometries of the two devices are so different that materially different arc-voltages are developed in each for a given current therethrough, an unequal division of current between the two interrupting devices 10 and 50 will occur. Although a substantially equal division is preferred, this unequal division may not be objectionable in certain applications, particularly since the previously-mentioned positive relationship of arc-voltage-to-current will still be present to prevent the above-described unstable condition from developing.

A triggered vacuum gap will not become conducting unless a predetermined voltage is present between its primary electrodes when it receives the triggering signal that causes sparkover of its trigger gap. When the interrupter 10 is arcing, the amount of voltage that will be present between the primary electrodes 51, 52 of triggered vacuum gap 50 is essentially equal to the arc-voltage developed by the vacuum interrupter 10. The instantaneous arc-voltage, in turn, varies directly with the instantaneous current through interrupter 10, as was pointed out hereinabove. We therefore set the overcurrent relay 62 to close its normally-open contacts only when the current through interrupter 10 is high enough to develop an arc-voltage sufficient to produce arc-over of the primary gap 53 when a triggering pulse is applied to the trigger gap 30 of triggered vacuum gap device 50. When the instantaneous current is at this level, the positive relationship between arc-voltage and current will be present and a substantially equal distribution of currents between the two interrupters will occur when both are conducting. The inclusion of a small amount of inductance in the parallel paths through the interrupting devices 10 and 50 can make available a higher voltage across the gap 53 for producing its initial arc-over upon triggering; and for this reason, we sometimes find it desirable to include this small amount of inductance. Preferably, any inductances present in the parallel paths are of substantial equal values.

Assume now that the triggered vacuum gap 50 has been triggered into a conducting state and that the total

current has been distributed between the interrupter 10 and gap device 50 until a natural current zero has been reached. The two arcs vanish at current zero, and the usual recovery voltage transient rapidly builds up across the two gaps that are then present in the interrupting devices 10 and 50. If the gaps can recover their dielectric strength at a higher rate than the rate at which the recovery voltage transient builds up, then the gaps will withstand the recovery voltage transient and the interruption will be completed. But if one of the gaps breaks down in response to the recovery voltage transient, arcing will be resumed across the gap and will continue until the next current zero. If it is the interrupter 10 that arcs over in response to the recovery voltage transient, then it will carry all of the resulting current until the instantaneous current reaches a predetermined value, at which point, the overcurrent relay 62 causes the triggered vacuum gap 50 to be inserted in the power circuit. Thereafter, the current is distributed substantially equally between the interrupters 10 and 50. It is assumed that relay 62 dropped-out at current zero and then picked up in response to said predetermined instantaneous current.

If it is the triggered vacuum gap 50 that arcs over in response to the recovery voltage transient, then it will initially carry all of the resulting current. But when the instantaneous current through gap 50 reaches a predetermined value, we trigger the then-open main interrupter 10 into conduction, causing it to assume its share of the total current. For triggering the main interrupter 10 into conduction, we provide a current transformer secondary winding 70 which is inductively coupled to the portion 57b of conductive bar 57 leading to the gap device 50. Across the current transformer secondary winding 70 an overcurrent relay 72 is connected. It is assumed that overcurrent relay 72 has dropped out at the first current zero. When instantaneous current of a predetermined magnitude flows through conductor 57b, the overcurrent relay 72 closes its normally-open contacts 72a to complete a turn-on circuit 73 for a pulse source 74. Pulse source 74 responds by delivering a triggering pulse to the trigger gap 30 of the interrupter 10. This renders the then-open interrupter 10 conducting, as previously described, thus providing parallel arcing paths through the two vacuum interrupters 10 and 50, as desired.

The main interrupter 10 of FIG. 1 is designed to carry the full continuous and momentary currents by itself. This eliminates the need for relatively movable contacts in the auxiliary interrupter 50, thus eliminating the need for mechanical operating means for interrupter 50 and also eliminating the need for a bellows in the interrupter 50. This all contributes to reduce costs.

In the modified embodiment of our invention shown in FIG. 2, two interrupters A and B identical to the interrupters of FIG. 1 are electrically connected in parallel. These interrupters are arranged to be opened approximately simultaneously by suitable means schematically shown at 80. Practically speaking, however, the opening operations of the two interrupters cannot be perfectly synchronized, and one set of contacts will part slightly after the other set. If there is enough inductance in the two parallel paths, an arc will be established at the contacts that first part. Another arc will be established at the remaining set of contacts when they part. Assuming a relatively high total current, there will be a substantially equal distribution of current between the interrupters.

At current zero the arcs will vanish, as explained in connection with FIG. 1, and the recovery voltage transient will rapidly build up across the two parallel gaps. If the recovery voltage transient is severe enough to break down one of the gaps, current will flow through this gap alone until it reaches a high enough value to cause overcurrent relay 62 or overcurrent relay 72, as the case may be, to operate. Operation of relay 62 or 72 results in the other vacuum interrupter being inserted into the power circuit, whereupon the total current is

shared substantially equally between the two interrupters.

A condition that has heretofore led to difficulties when an effort was made to operate interrupters in parallel has been the above-noted imperfect synchronization of the inter-
5 interrupter-opening operations. This imperfect synchronization could result in one of the interrupters opening just prior to current zero and the other inter-
10 rupter just after current zero. When two conventional vacuum interrupters, each with separable contacts, were connected in parallel and operated in this manner (i.e., with their opening operations slightly staggered on op-
15 posite sides of current zero), great difficulty was encountered in initiating an arc after the first current zero across the contacts that had opened prior to cur-
20 rent zero. With a moderate amount of inductance in series with each interrupter, the contacts that opened just prior to current zero could be made to draw an arc, but this arc could not be forced to resume after current
25 zero. After current zero, all the current flowed through the still-closed contacts of the other interrupter, and when these latter contacts opened, the resulting arc carried all the current. As a result, after such current zero, no current flowed through the contacts of the interrupter that had opened prior to current zero, thus preventing this first-opening interrupter from sharing in the re-
30 mainder of the interrupting operation.

In the circuit breakers of our invention, we are able to force all of the interrupters to bear their share of the interrupting duty during this portion of the inter-
35 ruption, even if operations of the two interrupters are staggered on opposite sides of current zero. In this respect, assume that one of the interrupters 10 (e.g., A) opens just prior to current zero, drawing an arc between its contacts 17, 18 which persists until current zero and then disappears. After current zero, all of the current will ini-
40 tially flow through the then-closed contacts of interrupter B. Interrupter B will alone carry this current until the instantaneous current reaches a predetermined value, at which time overcurrent relay 72 will pick up, thereby causing pulse source 74 to deliver a triggering pulse to
45 interrupter A. This renders the interrupter A conductive and thereafter the total current is distributed between both interrupter A and B. Thus, during the high current interval, the interrupting duty is distributed as desired between both interrupters even though their openings had been staggered on opposite sides of current zero.

This problem of operations staggered with respect to current zero is easily handled by the circuit breaker of FIG. 1. More specifically, assume that the contacts of interrupter 10 part just before current zero. This would
50 result in an arc which persisted until current zero and then vanished, whereupon the usual recovery voltage transient would build up. If the gap then present between the contacts of interrupter 10 can withstand this recovery voltage transient, the interruption is completed. But if the gap, which may then be quite short, again breaks
55 down, then an arc between contacts 17 and 18 will be reestablished and current flow through the interrupter 10 will resume.

When this current through interrupter 10 reaches a pre-
60 determined magnitude, it will cause the overcurrent relay 62 to pick up, thereby causing pulse source 64 to deliver a triggering pulse to trigger gap 30 of triggered vacuum gap 50. This renders the triggered vacuum gap 50 con-
65 ducting, and thereafter the total current is distributed as desired between the interrupter 10 and the triggered vacuum gap 50.

In the circuit breaker of FIG. 2, two control switches 66, respectively corresponding to the control switch 66 of FIG. 1, are provided for preventing operation of the pulse sources while the circuit breaker is closed. When a circuit-breaker opening operation is initiated, these switches 66 are opened by suitable means (not shown) to render the current-responsive relays 62 and 72 capable of responding to current through their associated inter-
70 rupters.

In application Serial No. 510,562, Lafferty, filed Nov. 30, 1965, and assigned to the assignee of the present invention it is pointed out that for alternating-current circuit applications, it is desirable that a trigger gap be
5 located adjacent each electrode in order to assure consistent breakdown of the primary gap in response to sparkover of the trigger gap. This provides assurance that a triggering arc will be established adjacent the primary electrode that is the cathode irrespective of the then-existing polarity of the voltage across the primary gap.

In the circuit breaker of FIG. 3, each of the inter-
10 rupters includes a pair of trigger gaps, one adjacent each electrode, as disclosed and claimed in the aforesaid Lafferty application. Each interrupter is the same as the correspondingly-designated interrupter shown in FIG. 1 except that an additional trigger gap has been added to each interrupter adjacent its lower electrode. This ad-
15 ditional trigger gap in each interrupter is designated 130 and is of essentially the same construction as the trigger gap 30 adjacent the upper electrode. Each of the trigger gaps 130 in a given interrupter is controlled by a pulse source which is operated in response to instantaneous current through the other interrupter in excess of a pre-
20 determined magnitude. In the schematic illustration, a current transformer 170 controls an overcurrent relay 172 which completes a turn-on circuit 173 for pulse source 174 when the current through gap 50 exceeds a predetermined value. A current transformer 160 controls an overcurrent relay 162, which completes a turn-on
25 circuit 163 for pulse source 164 when the current through interrupter 10 exceeds a predetermined value. Suitable means (not shown) is provided for causing the control switches 66 to open in response to circuit-breaker opening to allow the overcurrent relays to respond to overcurrents.

In the various illustrated embodiments, a separate pulse source has been shown for each trigger gap. This has
40 been done primarily to facilitate an understanding of the invention. It is to be understood that other suitable pulsing arrangements can equally well be used.

Although the illustrated circuit breakers include only two interrupting devices in parallel, it is to be understood that additional interrupters can be added to provide ad-
45 dition parallel arcing paths to impart additional interrupting capacity.

While we have shown and described particular embodi-
50 ments of our invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from our invention in its broader aspects; and we, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of our invention.

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

1. An electric circuit breaker comprising:

- (a) a first circuit interrupter of the vacuum-type comprising a highly-evacuated envelope and a pair of relatively movable contacts disposed within said envelope,
- (b) said contacts having a position of engagement in which they are effective to carry current through said circuit breaker,
- (c) said contacts being separable to establish an arc therebetween,
- (d) a second circuit interrupter of the triggered vacuum-type comprising a pair of primary electrodes within a highly evacuated space having a spaced-apart position and triggering means for establishing an arc between said primary electrodes when a pulse signal is applied to said triggering means,
- (e) means for connecting said primary electrodes in a circuit electrically in parallel with said contacts, and
- (f) means for causing the current passing through said circuit breaker to be divided between the arcing path between said contacts and an arcing path between said primary electrodes comprising: means respon-

sive to a condition which results in an arc being established between said contacts for applying a pulse signal to said triggering means while said inter-contact arc is present to establish an arc between said primary electrodes while said inter-contact arc is present.

2. The circuit breaker of claim 1 in which said means for applying a pulse signal to said triggering means operates in response to instantaneous current exceeding a predetermined magnitude flowing through said first circuit interrupter.

3. The circuit breaker of claim 1 in which said means for applying a pulse signal to said triggering means operates in response to instantaneous current exceeding a predetermined magnitude flowing through said first circuit interrupter, said predetermined current magnitude being sufficiently high that the instantaneous arc-voltage across said first interrupter is sufficiently high to produce an arc-over between said primary electrodes when said triggering means received said pulse signal.

4. The circuit breaker of claim 1 in which said means for applying a pulse signal to said triggering means operates in response to instantaneous current exceeding a predetermined magnitude flowing through said first vacuum-type circuit interrupter, said predetermined current magnitude being sufficiently high that the arc-voltage developed by said first vacuum-type circuit interrupter following breakdown of said second interrupter will vary directly with respect to current magnitude.

5. The circuit breaker of claim 1 in which said second interrupter is a triggered vacuum gap device in which said primary electrodes are disposed in spaced-apart relationship while the contacts of said first vacuum-type circuit interrupter are engaged.

6. The circuit breaker of claim 1 in which said second interrupter comprises relatively movable contacts constituting said primary electrodes and in which means is provided for opening the contacts of said two interrupters approximately simultaneously during an opening operation of said circuit breaker.

7. The circuit breaker of claim 1 in which said first vacuum-type circuit interrupter further comprises triggering means for establishing an arc between said contacts when they are spaced apart and a pulse signal is applied to said latter triggering means.

8. The circuit breaker of claim 1 in which said first vacuum-type circuit interrupter further comprises triggering means for establishing an arc between said contacts when they are spaced apart and a pulse signal is applied to said latter triggering means, and means for applying a pulse signal to the triggering means of said first vacuum-type circuit interrupter when the current through said second interrupter exceeds a predetermined value.

9. The circuit breaker of claim 1 in which said first

and second vacuum-type circuit interrupters are sufficiently similar in electrode or contact structure that they develop approximately equal arc voltages for a given value of instantaneous arcing current in the high current range where arc voltage varies as a direct function of current magnitude.

10. The circuit breaker of claim 1 in which each of said vacuum-type circuit interrupters has contacts or electrodes of a non-refractory metal and containing slots to assist in high current interruptions.

11. An electric circuit breaker comprising:

(a) a vacuum-type circuit interrupter comprising a highly-evacuated envelope and a pair of relatively movable contacts disposed within said envelope,

(b) said contacts having a position of engagement in which they are effective to carry current through said circuit breaker,

(c) said contacts being separable to establish an arc therebetween,

(d) interruption-assisting means for causing the total current flowing through said circuit breaker to be substantially equally distributed between said arc and one or more parallel arcing paths through said circuit breaker,

(e) said interruption-assisting means comprising a triggered vacuum interrupting device comprising: an evacuated envelope, a pair of primary electrodes connected in parallel with said arc and defining a portion of one of said parallel arcing paths, and triggering means for establishing an arc between said primary electrodes when a pulse signal is applied to said triggering means,

(f) and means for applying a pulse signal to said triggering means while said inter-contact arc is present to establish an arc between said primary electrodes while said inter-contact arc is present.

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