United States Patent

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[33] **Japan**
[31] **43/61186**

[54] **CIRCUIT INTERRUPTING APPARATUS**
3 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **335/195**
[51] **Int. Cl.** **H01h 77/10**
[50] **Field of Search** 335/195, 16; 200/146

[56] **References Cited**

UNITED STATES PATENTS

2,514,839	7/1950	Caswell	200/146
3,136,921	6/1964	Dorfman	335/195
3,345,485	10/1967	Engel	200/146

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Attorneys—Robert E. Burns and Emmanuel J. Lobato

ABSTRACT: A so-called no-fuse circuit breaker of a predetermined interrupting capacity is integrally combined with a current limiting circuit interrupter with contacts which are opened by electromagnetic force and having a larger interrupting capacity then the no-fuse circuit breaker. Overcurrents within the interrupting capacity of the no-fuse circuit breaker are interrupted by the same whereas overcurrents exceeding said interrupting capacity are interrupted by the current-limiting circuit interrupter before the no-fuse circuit breaker operates.

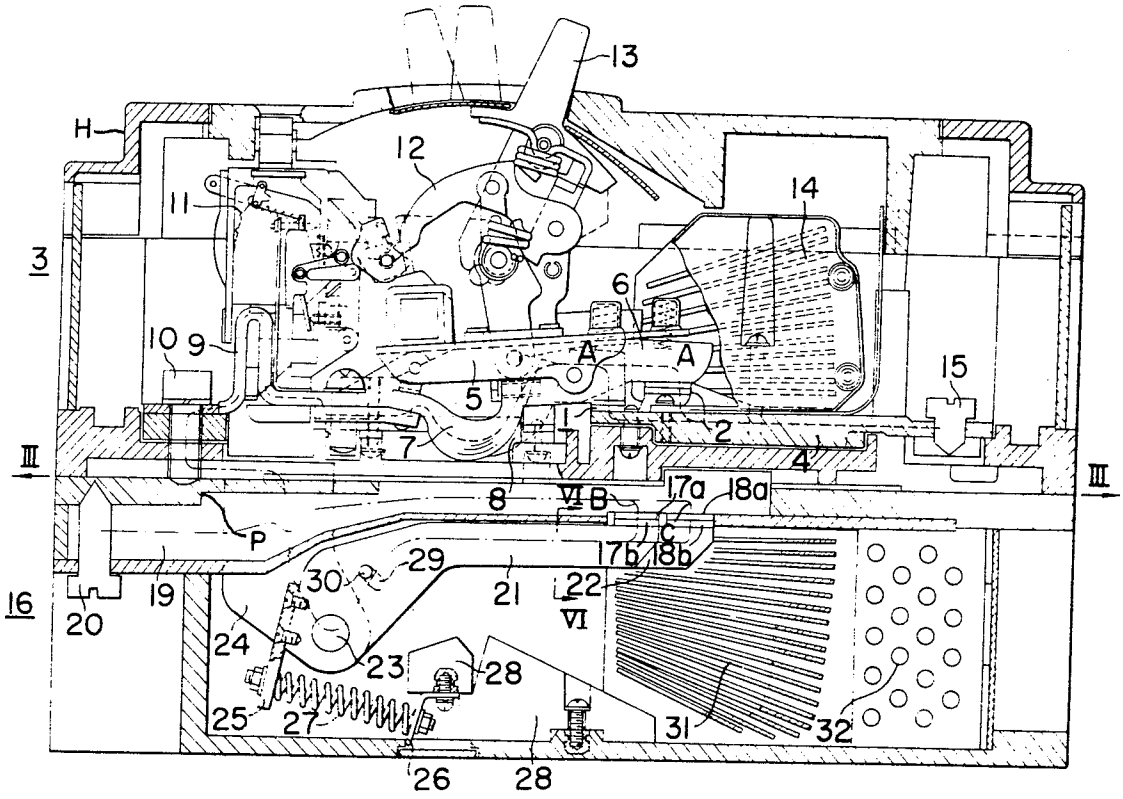


FIG. 1

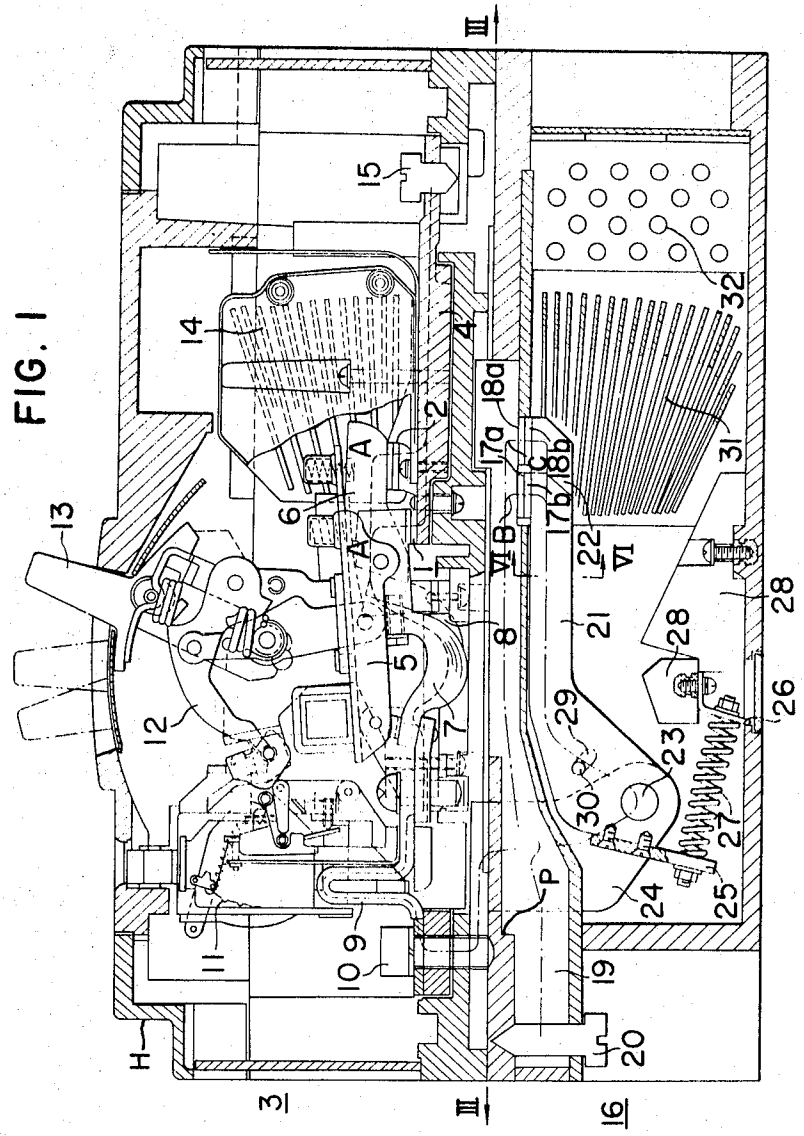

III
15
14
4
32
18a
17a
2
A
18b
17b
31
6
13
VI B
22
VI
28
21
8
28
5
29
26
12
7
23
30
27
24
25
P
10
9
11
19
20
H
31
III
16

FIG. 2

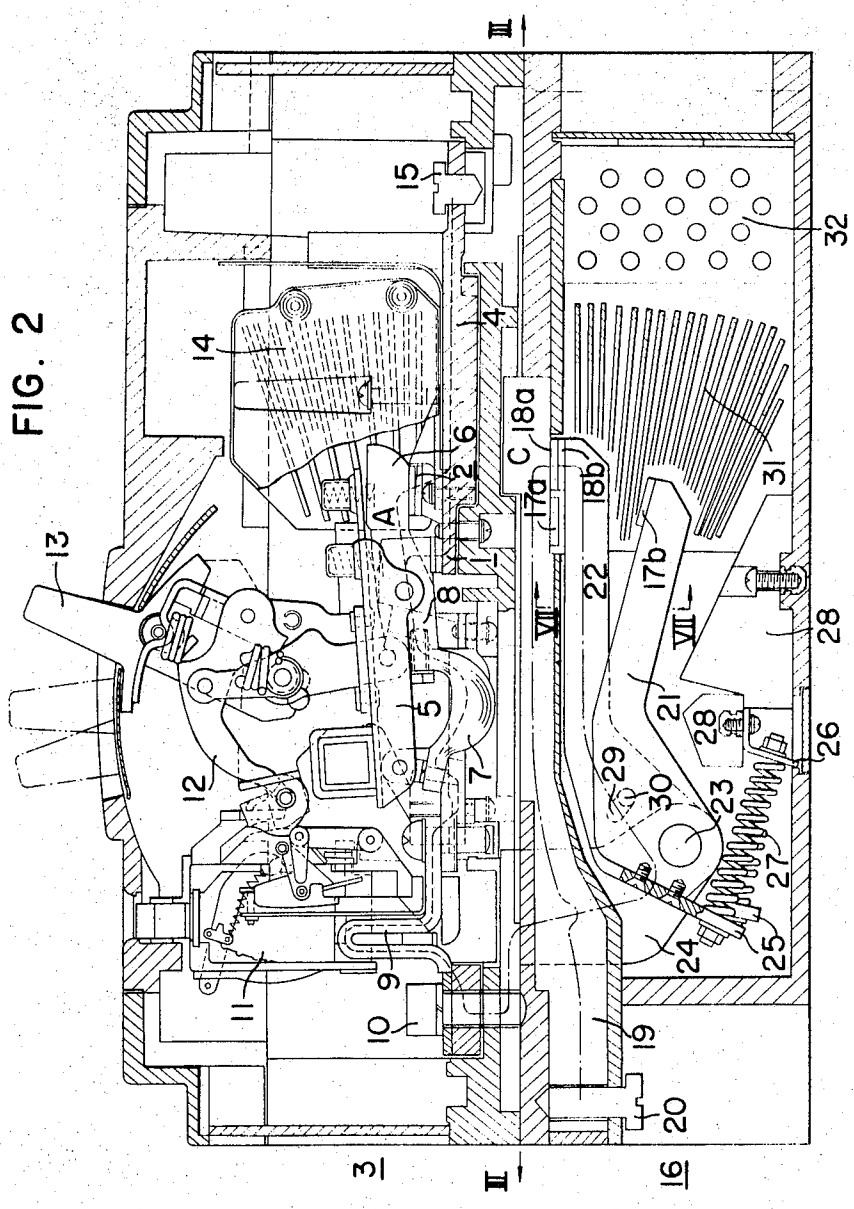

III
15
32
14
4
6
2
C
18a
17a
18b
A
31
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22
17b
VII
VII
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5
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12
7
29
30
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27
24
25
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11
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19
20
31
III
16

FIG. 3

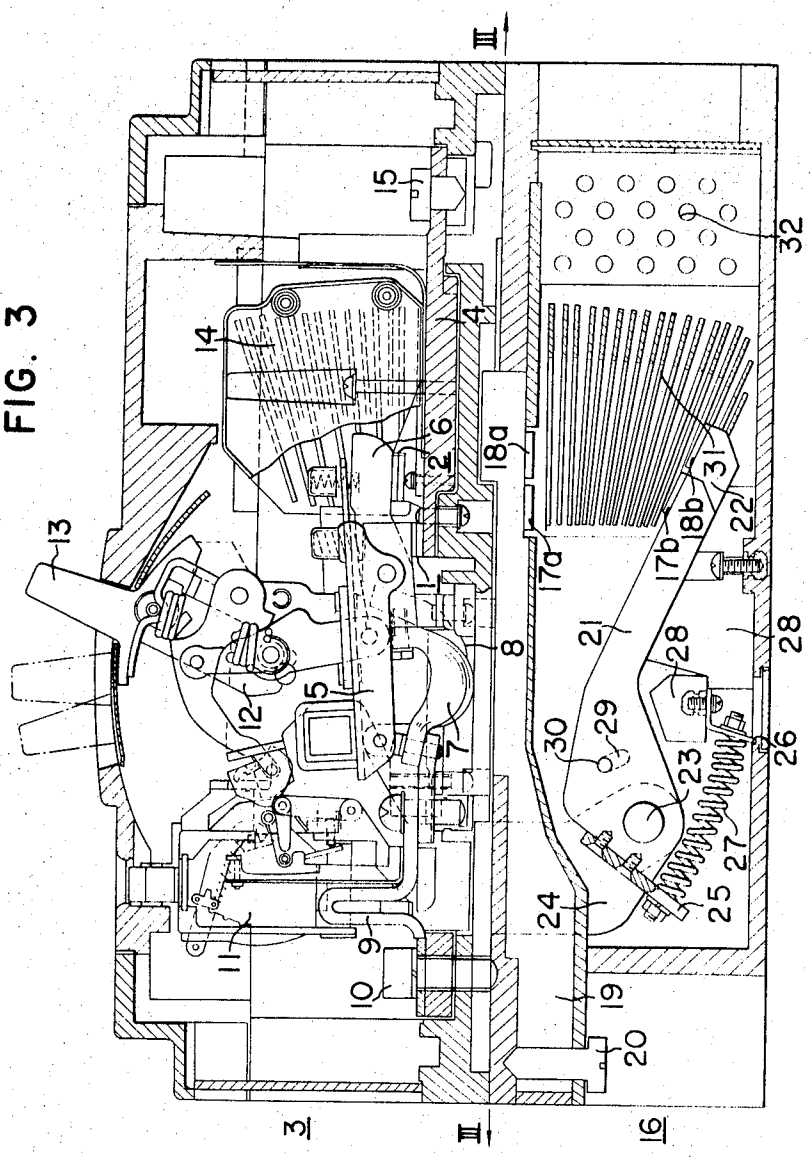

III
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32
14
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18a
31
22
18b
17b
17a
13
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11
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19
20
3
III
16

FIG. 4

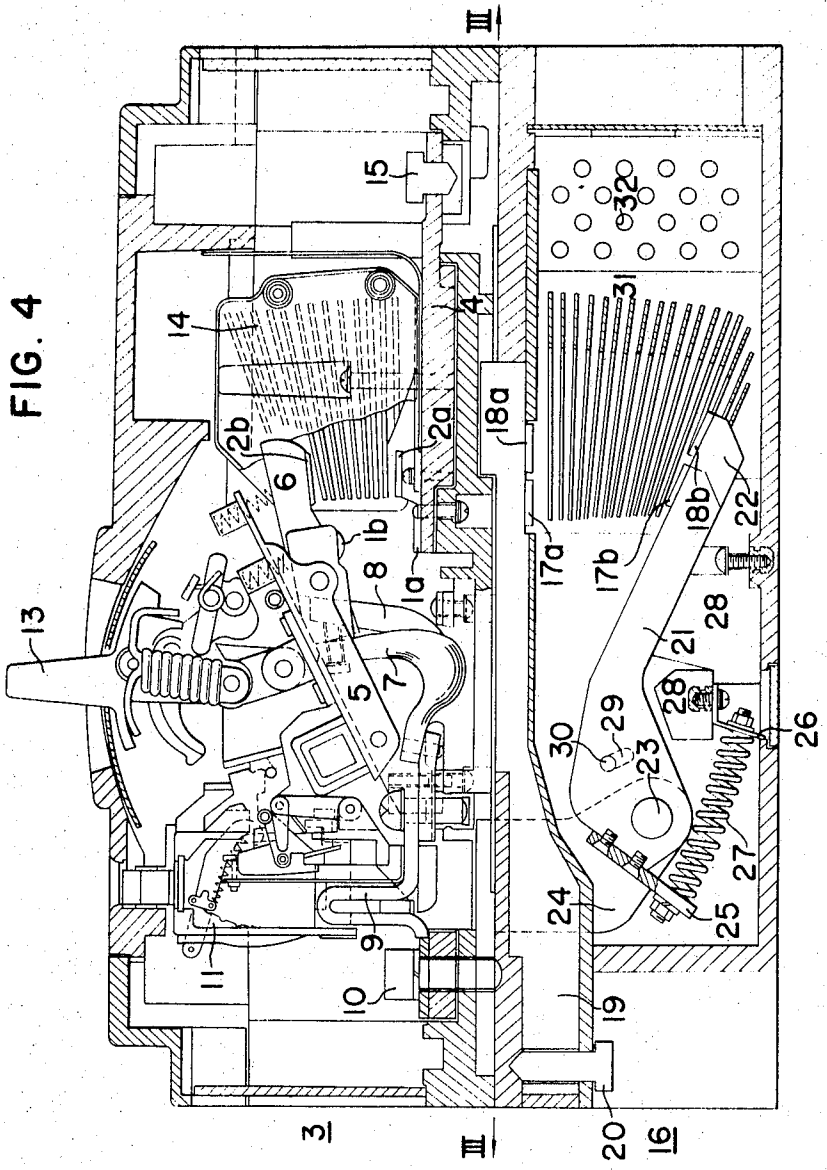

III
15
32
31
4
14
18a
2b
2a
6
1b
8
1a
17a
17b
18b
22
13
5
7
21
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29
30
23
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27
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25
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11
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19
20
16
3
III

FIG. 5

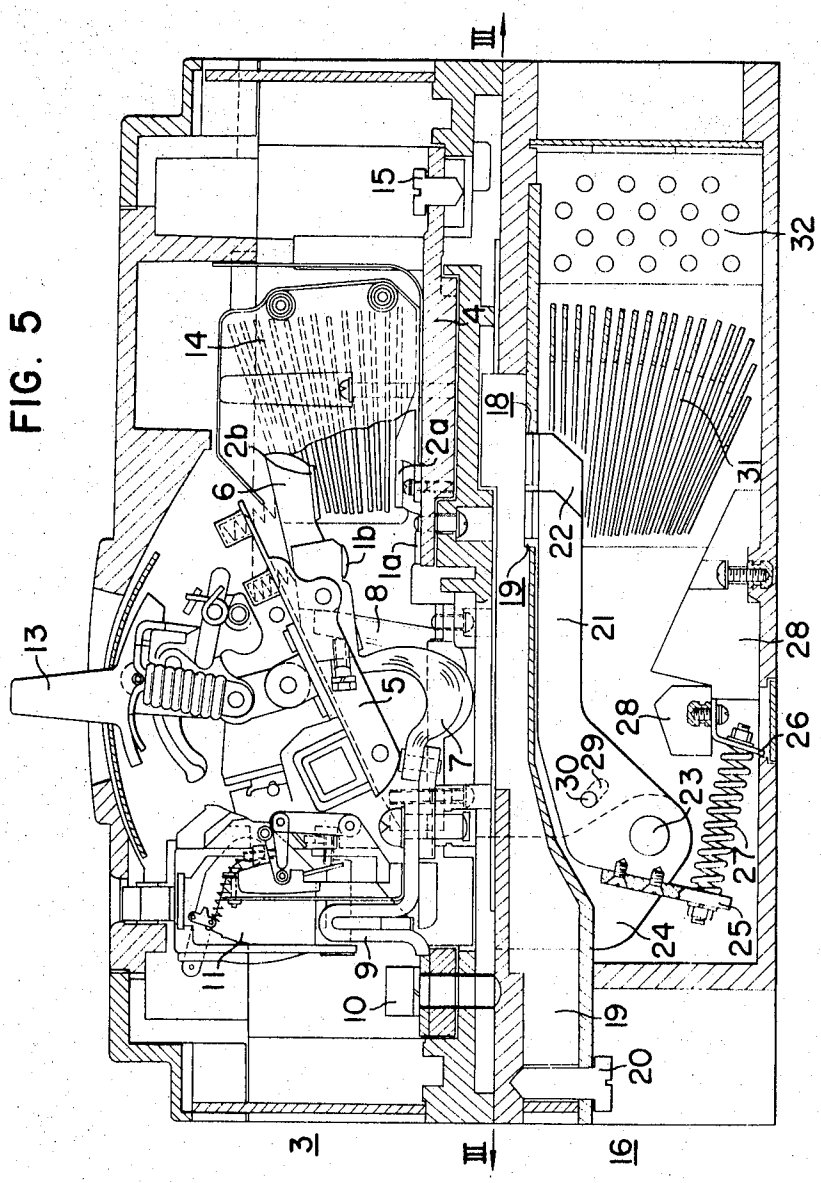

III
15
32
14
4
18
2b
2a
31
6
22
1b
1a
19
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21
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27
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III
16

FIG. 6

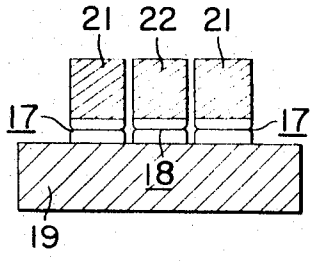


FIG. 7

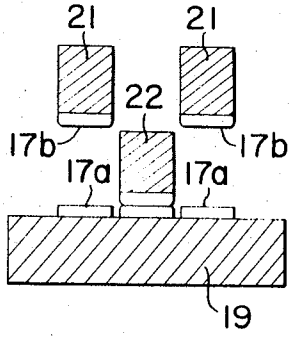
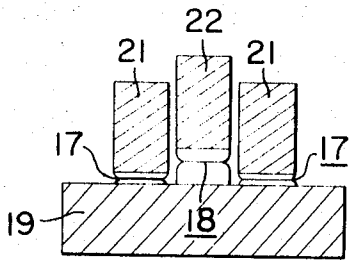


FIG. 8



CIRCUIT INTERRUPTING APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to circuit interrupting apparatus comprising an ordinary overcurrent circuit breaker including a thermal-tripping mechanism and an electromagnetic-tripping mechanism and a current-limiting circuit interrupter operated by electromagnetic repulsive force created between parallel current carrying conductors.

As is well known in the art, the ordinary hand-operated overcurrent circuit breaker to be mounted upon a switch board or the so-called no-fuse circuit breaker comprises an operating handle, at least one movable contact connected to the operating handle by a toggle mechanism, a catch to hold the toggle mechanism in the operative condition and tripping means responsive to overload condition to release the catch to open the contact. Where the overload condition is caused by the normal or relatively gradual change in the load current, it is not necessary or desirable to open the circuit breaker as soon as a predetermined overcurrent level is reached.

Usually source apparatus, such as generators, transformers, switches and the like have ample capacity to withstand relatively small overloads of short duration so that under these conditions it is not desirable to interrupt the circuit. For this purpose, a thermal-tripping mechanism having an inherent time delay is used. However, under short circuit or other dangerous overload conditions, it is necessary to trip open the circuit breaker as fast as possible. For this purpose, an electromagnetic-tripping mechanism is added. This mechanism comprises a magnetic core arranged to be magnetized by the current flowing through the circuit breaker and a magnetic armature arranged to be attracted by the core. For this reason, the construction of the overcurrent circuit breaker of a large current interrupting capacity is complicated and expensive. Moreover, due to such complicated mechanism, even when the circuit breaker is opened by the electromagnetic-tripping device certain delay time is unavoidable.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to increase the effective current interrupting capacity of the existing no-fuse circuit breakers.

This invention contemplates to accomplish this object by serially combining a conventional overcurrent circuit breaker with a current-limiting circuit interrupter wherein cooperating contacts are opened by the electromagnetic repulsive force created by the interaction between currents flowing through parallel or substantially parallel conductors. According to a preferred embodiment of this invention there are provided a pair of main contacts and pair of auxiliary or arcing contacts for the current-limiting circuit interrupter. The mechanism is constructed such that upon occurrence of over current the main contacts are first opened, and then the auxiliary contacts are opened. The current flowing through the auxiliary contacts are limited by selecting a material having higher specific resistance for the auxiliary contacts or conductors carrying the same.

The electromagnetic repulsive force F created by the interaction of currents flowing through two parallel conductors is expressed by

$$F=2.04(l/r)i^2\times10^{18}\ (\text{kg.})$$

where

l: length of parallel conductors (meters)

r: distance between parallel conductors (meter)

i: current flowing through parallel conductors (amperes)

By utilizing such a repulsive force it is possible to open the contacts substantially instantly which is to be compared with the time lap of the order of about 10 milliseconds of the electromagnetic-tripping device of the conventional no-fuse circuit breaker, thus minimizing damage to electric machines and apparatus connected to the circuit.

According to this invention, the operating current or current interrupting capacity of the current-limiting circuit interrupter is made considerably higher than that of the no-fuse circuit breaker. More particularly, overcurrent not exceeding the interrupting capacity of the no-fuse circuit breaker is cleared by the no-fuse circuit breaker whereas over currents exceeding the interrupting capacity of the no-fuse circuit breaker is cleared by the current-limiting circuit interruptor before the former operates. Under the last mentioned conditions, although the no-fuse circuit breaker also operates, its contacts may be opened under reduced current condition because of its above-described inherent delay time.

BRIEF DESCRIPTION OF THE DRAWING

In the accompanying drawing:

FIG. 1 shows a longitudinal section section of one example of an electric circuit-interrupting apparatus embodying this invention, the circuit-interrupting apparatus being shown in its closed state;

FIGS. 2, 3, 4 and 5 are similar longitudinal sectional views illustrating various steps of opening the circuit-interrupting apparatus;

FIG. 6 is a partial sectional view taken along a line VI—VI in FIG. 1;

FIG. 7 is a partial sectional view taken along a line VII—VII in FIG. 2; and

FIG. 8 is a partial sectional view of a modified embodiment of this invention taken along a line corresponding to line VI—VI in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The accompanying drawing shows circuit interrupting apparatus disposed in a housing H and divided by panel portions P into two parts on opposite sides of a reference plane designated by the line III—III in FIGS. 1–5. The portions above the line III—III illustrate a so-called no-fuse-type circuit breaker 3 including main contacts 1*a* and 1*b* and auxiliary contacts 2*a* and 2*b* (see FIG. 4). Main contacts 1*a* and 1*b* are mounted on a stationary conductor 4 and a movable conductor 5, respectively, while auxiliary contacts 2*a* and 2*b* are mounted on the stationary conductor 4 having a terminal 15 for connecting to an external circuit and a movable conductor 6, respectively. Movable conductors 5 and 6 are connected to one end of a heating element 9 via flexible conductors 7 and 8, respectively, opposite end of heating element 9 being connected to a connecting post 10. Thus, the overcurrent circuit breaker 3 comprises an overcurrent interrupting circuit A indicated by dotted lines and including stationary conductor 4, main contacts 1*a* and 1*b*, auxiliary contacts 2*a* and 2*b*, movable conductors 5 and 6, flexible conductors 7 and 8, heating element 9 and connecting post 10.

When a load current exceeding a predetermined value flows through the overcurrent interrupting circuit A, heating element 9 actuates a tripping device 11 to trip an operating mechanism 12 of the conventional construction thus interrupting the overcurrent interrupting circuit A. As is well known in the art the operating mechanism 12 is provided with a suitable operating handle 13 and a suitable arc extinguishing device 14 is associated with auxiliary contacts 2*a* and 2*b*.

The novel current-limiting circuit interruptor 16 shown below line III—III in FIGS. 1 through 5 will now be described.

The current limiting circuit interruptor 16 comprises main contacts 17*a* and 17*b* and auxiliary contacts 18*a* and 18*b*, stationary main contact 17*a* and stationary auxiliary contact 18*a* being mounted on the inner end of a stationary conductor 19. The opposite end of the stationary conductor 19 is connected to a terminal post 20 for connecting it to the external circuit.

Two main movable conductors 21 and a auxiliary movable conductor 22 which oppose stationary conductor 19, are disposed in parallel with each other in the circuit closed position shown in FIG. 1. Main movable contact 17*b* is mounted on the inner end of each main movable conductor 21, while auxiliary movable contact 18*b* is mounted on the inner end of auxiliary movable conductor 22. Main and auxiliary movable

conductors 21 and 22 are pivotally mounted on a transverse pin 23 journaled by stationary arms 24 electrically connected to terminal post 10. Tension springs 27 are connected between levers 25 secured to the outer ends of main and auxiliary movable conductors 21 and 22 and an L-shaped stationary arm 26 to normally urge movable contacts 17*b* and 18*b* against stationary contacts 17*a* and 18*a*, respectively.

As shown in FIG. 6, in the closed position, stationary conductor 19, main movable conductors 21 and auxiliary movable conductor 22 are arranged in parallel with small gaps therebetween. Usually, two or more main movable conductors 21 are disposed on the opposite sides of the auxiliary movable conductor 22.

As shown by dot and dash lines in FIG. 1, the current limiting circuit interrupter 16 comprises a main contact circuit B including stationary arm 24, main movable conductors 21, main contacts 17*a* and 17*b* and stationary conductor 19, and an auxiliary contact circuit C including stationary arm 4, auxiliary movable conductor 22, auxiliary contacts 18*a* and 18*b* and stationary conductor 19.

As shown, the overcurrent circuit breaker 3 and the current limiting circuit interrupter 16 are assembled into a unitary structure in back-to-back contact relationship.

When current flows through the main contact circuit B and auxiliary contact circuit C, current flows in the same direction through main and auxiliary movable conductors 21 and 22 but in the opposite directions through stationary conductor 19 and through main and auxiliary movable conductors 21 and 22 so that electromagnetic repulsive forces are created between stationary conductor 19 and main and auxiliary movable conductors 21 and 22, said electromagnetic repulsive force acting in the direction opposite to that of the force of springs 27. At the same time, as the current flows in the same direction through movable conductor 6 of the overload circuit breaker and stationary conductor 19, an attractive force is created between these conductors, tending to hold conductor 6 in its closed position. As long as the magnitude of the current flowing through main contact circuit B and auxiliary contact circuit C is less than a predetermined value, said electromagnetic repulsive force is generally smaller than the force of springs 27 so that main and auxiliary movable conductors 21 and 22 will not be moved. However, should an excessively large current flow through main and auxiliary contact circuits B and C due to a short circuit or the like, the electromagnetic repulsive force between stationary conductor 19 and main and auxiliary movable conductors 21 and 22 will exceed the force of springs 27 to rotate main and auxiliary movable conductors 21 and 22 about pivot pin 23 in the clockwise direction thereby to interrupt main contact circuit B and auxiliary contact circuit C. A stop 28 made of rubber and the like may be provided to cushion the movement of movable conductors 21 and 22. At the same time, the overload circuit breaker 3 is tripped open as above described.

As is well known in the art, in an interruptor with main contacts and auxiliary or arcing contacts, it is usual to first interrupt the main contacts and then the auxiliary contacts. A current-limiting resistor is included in circuit with the auxiliary contacts usually made of arc resistant material such as carbon, tungsten alloy or the like. In accordance with this invention the current-limiting interrupter 16 is connected in series with the main or no-fuse overload circuit breaker 3 and the contacts of the current-limiting interruptor is opened by the electromagnetic repulsive force created between stationary and movable conductors. In accordance with the illustrated embodiment the required current limiting action and delayed opening of the auxiliary contacts are provided in the following manner. The resistivity of the material comprising the main contacts 17 or that of the main conductor 21 is made lower than that of the auxiliary contacts 18 or of the auxiliary movable conductor 22 to cause more current to normally flow through the main contact circuit B than through the auxiliary contact circuit C or to limit the current flowing through auxiliary contacts after the main contacts have been opened. A decrease in the current flowing through auxiliary contacts after opening the main contacts result in a decrease in the electromagnetic repulsive force. Alternatively, the force of spring 27 associated with the main movable conductor 21 may be made smaller than that of spring 27 associated with the auxiliary movable conductor 22. In any case, the opening force corresponding to the difference between the electromagnetic repulsive force and the bias of the spring 27 is larger for the main movable conductor 21 than that for the auxiliary movable conductor 22. Alternatively, the electromagnetic repulsive force acting between stationary conductor 19 and main movable conductor 21 may be made larger than that acting between stationary conductor 19 and auxiliary movable conductor 22 by designing the gap between the main conductor 19 and main movable conductor 21 to be smaller than the gap between stationary conductor 19 and auxiliary movable conductor 22. Auxiliary movable conductor 22 is formed with an elongated slot 29 to receive a pin 30 secured to the main movable conductor 21. As depicted in FIG. 1 pin 30 engaged one end of slot 29 at the contact closed position of the circuit interruptor. Thus, the auxiliary movable conductor 22 is permitted to move only after main movable conductor 21 has moved a predetermined distance. A suitable arc extinguishing device shown as an arc-chute 31 and an arc-cooling plate 32 is associated with auxiliary contacts 18. It is preferable to cause the auxiliary movable conductor 22 carrying auxiliary contact 18*b* to extend more deeply into the arc chute to decrease the size thereof. As will be seen in the drawings, the arc extinguishing device 31 for the current limiting interrupter 16 and the arc-extinguishing device 14 for the overload circuit breaker 3 extend in the same direction so that ionized gases resulting from the discharge when the respective contacts are opened are exhausted in the same direction.

The novel circuit-interrupting apparatus operates as follows:

As shown in FIG. 1, in the closed position, the load current flows from terminal 15 to terminal 20 through circuit A in the overcurrent circuit breaker 3, connecting post 10, main contact circuit B and auxiliary contact circuit C in the current limiting interrupter 16. As above-described, the operating current of the overcurrent circuit breaker 3 is set to a value lower than that of the current-limiting circuit interrupter 16. As a result, when the overload current is smaller than the operating current of the current limiting interrupter 16 only overcurrent circuit breaker 3 operates to interrupt the load circuit, as shown in FIG. 5. Upon occurrence of a very heavy over current through the interruptor circuit due to a short circuit fault and the like, the electromagnetic repulsive force created by the interaction of currents flowing through stationary conductor 19 and main movable conductors 21 first rotates main movable conductors 21 to the position shown in FIGS. 2 and 7 to interrupt the main contact circuit B. Then, the electromagnetic repulsive force created by the interaction of currents flowing through stationary conductor 19 and auxiliary movable conductor 22 rotates the latter conductor to interrupt auxiliary contact circuit C as shown in FIG. 3. While main and auxiliary movable conductors 21 and 22 are operated instantaneously, overcurrent circuit breaker 3 does not yet operate because of its inherent time lag caused by its complicated mechanism. While the electric arc struck between auxiliary contacts 18*a* and 18*b* upon interruption of the auxiliary contact circuit C is still persisting overcurrent circuit breaker 3 may be opened as shown in FIG. 4, but there is no risk of damaging it because the fault current has been limited to a safe value by the current-limiting circuit interruptor. Upon opening of the overcurrent circuit breaker the electromagnetic repulsive forces between stationary conductor 19 and main and auxiliary movable conductors 21 and 22 disappear so that main and auxiliary movable conductors 21 and 22 are restored to the closed position by the action of springs 27. However, overcurrent circuit breaker 3 is locked in the opened condition until it is reclosed by operating handle 13. Since overcurrent circuit breaker 3 and current limiting cir-

cuit interruptor 16 are designed to have interrupting currents which overlap each other, there is no insensitive zone wherein the circuit-interrupting apparatus fails to clear the fault. To use the novel circuit-interrupting apparatus for a load circuits having a current rating of 1,200 amperes, for example, the operating current of the over current circuit breaker 3 is set to 2,500 amperes, and the operating currents of the main and the auxiliary movable conductors 21 and 22 are set to 10,000 amperes and 15,000 amperes, respectively.

Thus, it will be clear that according to this invention, even excessively large overcurrent which are difficult to be effectively interrupted by the ordinary overcurrent circuit beaker of a limited interrupted capacity can be effectively interrupted. In other words, the effective interrupting capacity of the ordinary overcurrent circuit breaker is greatly increased by the addition of the current-limiting circuit interruptor of relatively simple and rugged construction. Moreover, a large current exceeding the interrupting capacity of the overcurrent circuit breaker having an interrupting time of the order of about 20 milliseconds can be satisfactorily interrupted within several milliseconds, thus decreasing the damage to machines and apparatus connnected to the circuit interrupter. Further, as the overcurrent circuit breaker and the current-limiting circuit interrupter are combined into a unitary structure, the interrupting apparatus as a whole is relatively compact and requires a small space.

We claim:

1. A circuit interrupting apparatus comprising a mounting panel means having opposite faces and an overload circuit breaker of a predetermined interrupting capacity and a current limiting circuit interrupter of greater interrupting capacity disposed back-to-back on opposite faces of said panel means;

said current-limiting circuit interrupter comprising a stationary conductor mounted on one face of said panel means and having a contact, a movable conductor having a contact and mounted on said one face of said panel for movement in a direction away from said stationary conductor from a closed position in which said movable conductor is substantially parallel to said stationary conductor and said contacts are in engagement with one another to an open position in which said contacts are disengaged;

said overload circuit breaker comprising a stationary contact mounted on the opposite face of said panel means and a movable conductor carrying a movable contact and mounted on said opposite face of said panel means for movement in a direction away from said stationary conductor of said current limiting circuit interrupter from a closed position in which said stationary contact and said movable contact are in engagement with one another and said movable conductor of said overload circuit breaker is substantially parallel to said stationary conductor of said current-limiting circuit interrupter to an open position in which said contacts are disengaged, and trip means for moving said movable conductor of said overload circuit breaker from closed to open position upon the occurrence of a predetermined overload current;

said movable conductors being within the range of the electromagnetic field of said stationary conductor when said movable conductors are in closed position,

and means connecting said overload circuit breaker and said current-limiting interrupter in series with one another in the manner that when both said movable conductors are in closed position current flows in opposite directions in said stationary conductor and said movable conductor of said current-limiting circuit interrupter to create an electromagnetic repulsive force to open said current-limiting circuit interrupter upon the occurrence of the current of a predetermined magnitude greater than said overload current for opening said overload circuit breaker, and current flows in the same direction in said stationary conductor and said movable conductor of said overload circuit breaker to create an electromagnetic attractive force to delay the opening of said overload circuit breaker until after said current-limiting circuit interrupter has opened.

2. The circuit-interrupting apparatus according to claim 1, wherein each of said overload circuit breaker and said current-limiting interrupter is provided with an arc-extinguishing device associated with separable contacts thereof, the arc-extinguishing devices of said overload circuit breaker and of said current-limiting circuit breaker being directed in the same direction to exhaust ionized gas in the same direction.

3. The circuit-interrupting apparatus according to claim 1, wherein said stationary conductor of said current-limiting circuit interrupter has a main contact and an auxiliary contact and said movable conductor of said current-limiting circuit interrupter comprises a main movable conductor carrying a main contact and an auxiliary movable conductor carrying an auxiliary contact, said main conductor and auxiliary conductor being interconnected by a pin and slot connection so as to cause said main contacts to open prior to the opening of said auxiliary contacts.