Sept. 26, 1933. F. KESSELRING ET AL 1,927,893

CIRCUIT INTERRUPTER

Filed Jan. 22, 1931 2 Sheets-Sheet 1

Fig. 1.

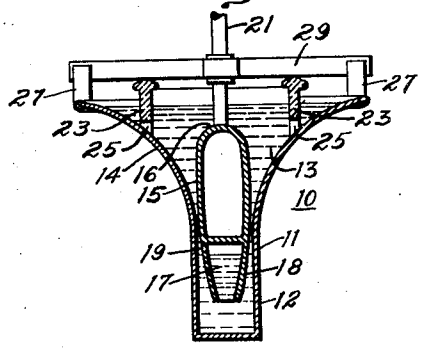


Fig. 2.

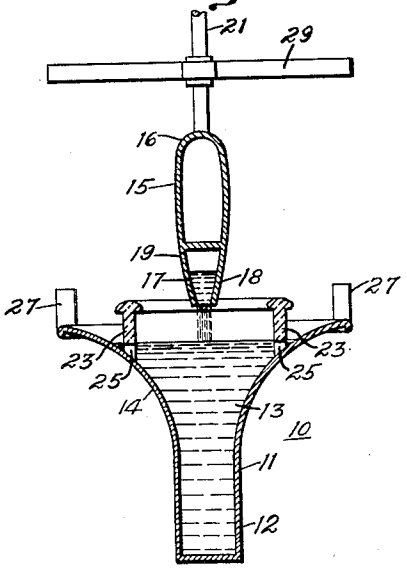


Fig. 3.

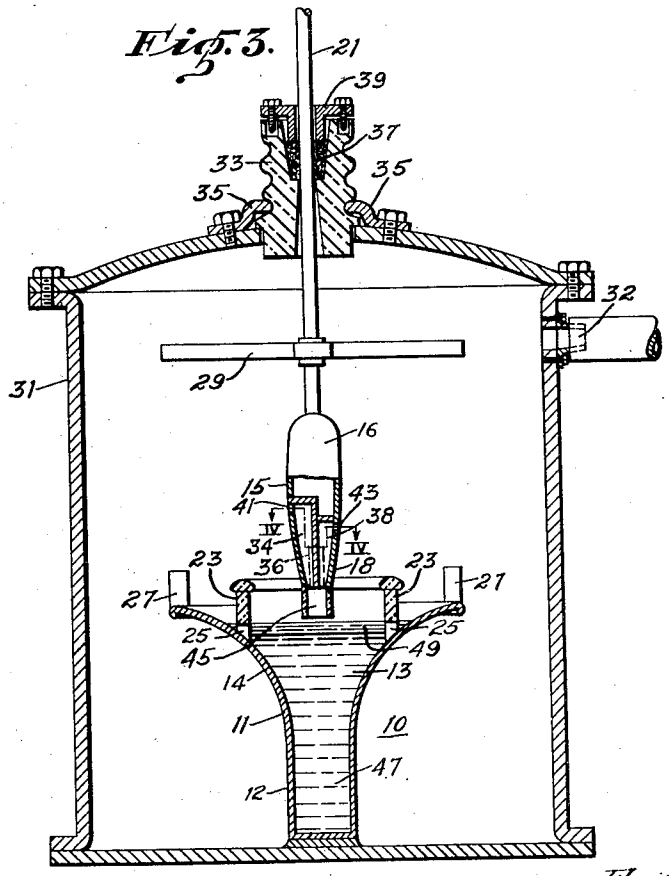
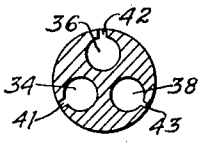


Fig. 4.



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Fig. 5.

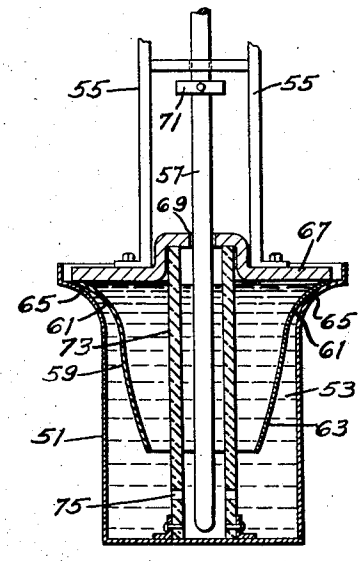


Fig. 6.

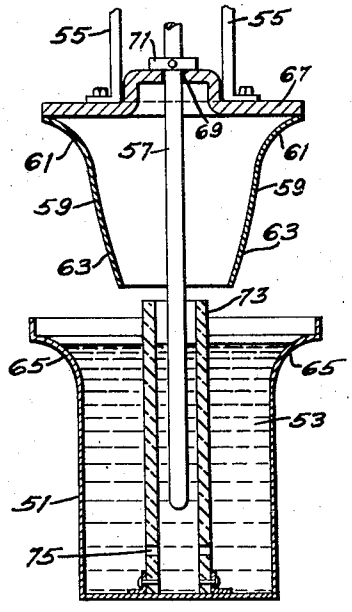
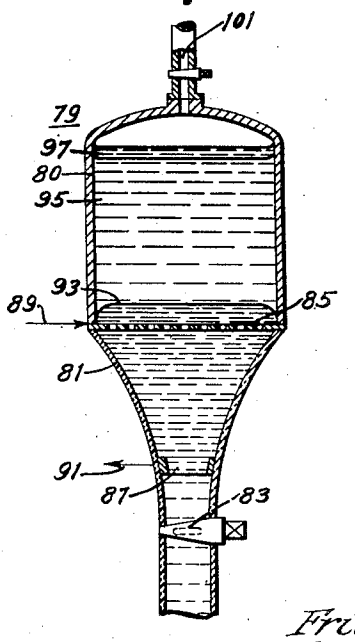


Fig. 7.



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UNITED STATES PATENT OFFICE

1,927,893

CIRCUIT INTERRUPTER

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Application January 22, 1931, Serial No. 510,448, and in Germany January 25, 1930

7 Claims. (Cl. 200—152)

Our invention relates to a circuit interrupter and more particularly to a device of the type in which the resistance of a body of liquid connected in the circuit is increased.

An object of our invention is to provide a liquid resistance circuit breaker which is so constructed that there is not sufficient heat generated in any portion of the liquid, when a circuit is interrupted, to raise the temperature of any portion of the liquid to its boiling point.

A further object of the invention is to provide a circuit interrupter in which the increase in resistance is obtained by decreasing the area of contact between a moving conducting member and the liquid and by increasing the length of the conducting path.

A further object of the invention is to provide an insulating arc barrier between the conducting members of the circuit breaker at the surface of the liquid.

When a circuit is interrupted by inserting the resistance of a body of liquid in the circuit, the circuit interrupter must be so constructed that the amount of heat generated by the resistance of the liquid in any portion thereof must be less than the amount of heat which will raise the temperature of that portion of the liquid to its boiling point. This may be expressed mathematically by the following equation:

$$\int_0^{t_a} j^2 S \cdot dt < c(T_p - T_o) \qquad (1)$$

Where:

j=current density in amps/sq. cm.

S=specific resistance of liquid in $\frac{\text{ohm}}{\text{cm.}^3}$

t_a=time of switching

c=specific heat of liquid in $\frac{\text{watt sec.}}{\text{cu. cm. degree}}$

T_p=boiling point of liquid with pressure p

T_o=temperature of liquid for time, $t=o$

The expression on the left-hand side of this equation shows that the product of the square of the current density and the specific resistance of the liquid for a given interval of time must be kept smaller than the specific heat of the liquid multiplied by the increase in temperature necessary to raise the liquid to its boiling point. The resistance of a liquid may be varied in either of two methods. The cross section of the effective body of the liquid may be decreased or the length of the body of the liquid may be increased. The reduction in cross section of the body of liquid increases the current density so that, if this reduction in cross-section is carried beyond a certain point, it is seen from the equation above that the value of the left-hand side of the equation will be increased above the value of the right-hand side. It is, therefore, necessary to construct a liquid circuit interrupter so that the current density is not increased above a given value depending upon the type of liquid used.

From the equations above, it is also seen that the condition for successful operation of the circuit breaker may be fulfilled by increasing the pressure on the liquid, thus raising its boiling point.

If a liquid resistance circuit interrupter is made using a conducting container holding a large volume of liquid with a small electrode immersed therein, the opening of the interrupter by withdrawing the electrode will insert an increasing resistance in the circuit. This will be due largely to the decrease in the surface area of the electrode, thereby increasing the current density. The length of the conducting path, however, will not be very materially increased. It is readily seen that, just before the electrode leaves the liquid, the area of contact will be infinitely small and the current density will be infinitely large so that the liquid will be raised to its boiling point. This is overcome in applicants' circuit breaker by decreasing the surface area of the moving conducting member only to the point where the limiting value of the current density is reached and then increasing the length of the conducting portion of the liquid without decreasing its cross-sectional area. The resistance of the liquid can be increased in this manner so that the current is decreased to a very small value just before the moving conducting member leaves the liquid so that the heat generated will not raise the temperature of the liquid to its boiling point.

The foregoing objects of our invention will be further understood from the accompanying drawings which illustrate several practical embodiments of the invention and in which

Figure 1 is an elevational view, partially in section, of one form of our circuit interrupter in closed position.

Fig. 2 is a similar view showing the circuit breaker in open position.

Fig. 3 is a sectional view, partly in elevation, of a modified form of the circuit interrupter illustrated in Figs. 1 and 2.

Fig. 4 is a sectional view through Fig. 3 on line IV—IV.

Figs. 5 and 6 show another form of our inven-

tion, partially in section and partially in elevation, in its closed and partly opened positions respectively.

Fig. 7 is a sectional view of a further modified form of the invention.

Referring to Fig. 1, our circuit interrupter 10 comprises a container or tank 11 filled with a conducting fluid 13 and in which a movable conducting member 15 is inserted. The container 11 is made of conducting material and is electrically connected to one side of the circuit. This container is constructed with a small cross-section at its bottom portion 12 and gradually flares outwardly to a large cross-section at its upper portion 14. The movable conducting member 15 is tubular in form with a rounded top 16 and a tapered lower portion 18. The exterior of this movable conducting member is streamlined so as to prevent turbulence of the liquid as it is moved therein. The lower portion 18 of conducting member 15 is provided with a cavity 17 for retaining a portion of the liquid. The cavity 17 has a nozzle-shaped opening at its lower end and small air holes 19 at its upper end. Conducting member 15 is moved out of the liquid by an actuating rod 21 which is operated by a mechanism not shown.

When the moving conducting member is in its lower position, the effective current path between the moving member, which is electrically connected to one side of the electrical circuit, and the container 11 is of large cross-section and small length. As the member 15 is moved out of the liquid, its area of contact therewith is decreased with a resulting decrease in the cross-section of the liquid which is effective for conducting the current. At the same time, the length of the current path is increased, due to the outward flare 14 of the container 11 and the inward taper 18 of the member 15. When the end of the movable member 15 reaches the surface of the liquid, the cross-section of the conducting portion of the liquid has been reduced to substantially the area of the end of the nozzle 18.

As the member 15 is further raised out of the liquid, the portion of the liquid which has been retained within the cavity 17, is released as air enters the holes 19. This provides a jet of liquid which flows from the cavity 17 to the main body of the liquid 13, as illustrated in Fig. 2. This provides a current path of increasing length and uniform cross-section. The rate of flow of the liquid is regulated by the size of the opening of the nozzle and the size of the air holes 19. The cavity 17 is made of sufficient size to provide a continuous stream of liquid until the current has been reduced to a low value, such as 5 amperes, at which substantially no arc will be produced, when the circuit is completely interrupted due to the fact that all of the liquid has run out of the cavity 17. The liquid 13 may be water or any other conducting fluid. If it is desired, the conductivity of the liquid may be increased by adding thereto a substance, such as ordinary salt.

The container 11 is provided with an ionization barrier 23 of insulating material. This barrier is provided at the surface of the liquid to prevent a flashover or arc from the moving electrode 15 to the container 11. Barrier 23 has openings 25 at its base to permit free flow of the liquid between the portions on each side of the barrier.

Container 11 is provided at its upper edge with contact jaws 27 for making an electrical connection with a conducting bar 29 which is carried by the conducting actuating rod 21. This makes a solid electrical connection between the moving conducting member and the tank 11 after the resistance of the liquid has been reduced to a minimum when the circuit breaker is closed.

Referring to Fig. 3, where similar reference characters indicate the same parts as in Figs. 1 and 2, our circuit interrupter 10 is enclosed in an air-tight tank 31 having a connection 32 for supplying compressed air or other gas, such as hydrogen, for maintaining the liquid 13 under pressure greater than that due to the atmosphere. The operating rod 21 is actuated through an insulating bushing 33 which is secured to the top of the tank 31 by a flanged collar 35. The top of the insulator 33 is provided with packing 37 and a gland 39 for maintaining an airtight joint with the operating rod 21. This provision of means for maintaining the liquid of the circuit breaker under pressure, raises the boiling point of the liquid thus increasing the capacity of the circuit breaker due to the increase in the value of the right-hand side of the equation given above.

As shown in Figs. 3 and 4, the movable conducting member 15 is provided with a plurality of cavities 34, 36 and 38, each of which is made of a different length so that the jets of liquid which flow therefrom will stop after different lengths of time. This provides means for reducing the cross-sectional area of the flowing stream of liquid after the moving member has left the surface of the liquid and the flow of current has been reduced. Each of the cavities is provided with air inlets 41, 42 and 43 which are of different sizes to cause different rates of flow in each of the three jets.

The end 18 of the moving member 15 is also provided with an insulating tube 45 which acts as a smooth nozzle to reduce the turbulence of the flowing stream of liquid. By making member 45 of insulation, the area of electrical connection between the member 15 and the liquid 13 is broken when the end 18 of the conducting member 15 leaves the liquid but the liquid jet is still prevented from falling freely to the main body of the liquid 13.

A further feature of the modification of the invention illustrated in Fig. 3 lies in having the liquid 13 consist of several layers of different liquids having different specific resistances so chosen that the liquid having the highest specific resistance also has the lowest specific gravity. The liquids are also such that they are non-miscible so that they will float in separate layers. In the drawings, two layers are shown, with the lower layer 47 consisting of water and the upper layer 49 of oil. By using a plurality of different liquids, an increasing resistance is obtained as the moving member 15 is raised, due to the insertion of the liquids of higher specific resistances. Since the liquids used have positive temperature coefficients of resistance, the resistance of the liquid is increased as it becomes heated, thus further reducing the flow of current.

A further modification of the invention is illustrated in Figs. 5 and 6. A conducting container 51 is filled with a conducting fluid 53 and electrically connected to one side of the circuit to be interrupted. The other side of the circuit is connected to the operating rods 55. The connection is made with the liquid 53 through a pair of conducting members 57 and 59.

Member 59 comprises a metal tube having a large area and which is outwardly flared at its upper portion 61 and inwardly tapered at its lower

portion 63. The container 51 is also outwardly flared at its top 65. The outwardly flared portion 61 of the member 59, and 65 of container 51 are of the same size so that when the conducting member 59 is in its lowermost position, a solid electrical connection is made between the two members. The conducting member 59 is supported from a top 67 to which the actuating rods 55 are secured.

The moving conducting rod 57 extends through a hole 69 in the top 67 and is provided with a collar 71. The container 51 has secured therein an insulating tubular member 73 which extends from a point above the surface of the liquid 53, to the bottom of the container. The tubular member 73 is of a relatively small cross-section and has openings 75 near the bottom thereof to permit flow of the liquid..

When the actuating rods 55 are raised to open the circuit interrupter, the tubular conducting member 59 is raised until it is almost out of the liquid when the collar 71 on rod 57 is engaged by the top 67, thus raising the conducting rod 57. It is thus seen that the resistance through the liquid is increased by diminishing the area of contact of the member 59 with the liquid 53 and by the increase in the length of the conducting path due to the outward flare 65 of the container and the inward taper 63 of the movable conducting member. When the tubular conducting member 59 has left the liquid, the effective conducting portion of the liquid is then that within the insulating tube 73. As the conducting rod 57 is moved out of the insulating tube, the effective area of contact between the rod and the liquid remains substantially constant, but the length of the current path in the liquid is increased as the rod is raised. This provides a conducting path of substantially uniform cross-section and increasing length so that the current density does not reach a value at which the boiling point of the liquid is reached.

In the modification of the invention illustrated in Fig. 7, a container 79 is provided with an upper portion 80 of uniform section and an inwardly flared lower portion 81 of insulating material. The narrow portion at the lower end 81 of the container is closed by a valve 83. A perforated metallic electrode 85 is secured between the portions 80 and 81 of the container 79. A second electrode 87 is secured near the lower end of the narrow tubular portion 81 of the container. These two electrodes are connected to the circuit to be controlled through wires 89 and 91. When the circuit is closed, a connection is made between the electrodes 85 and 87 by a body of highly conducting liquid, such as mercury 93. The container is filled above the mercury with a liquid, such as water 95, which is less conducting than the mercury. A third layer of liquid, such as oil 97, is arranged above the water 95. When it is desired to interrupt the circuit, the valve 83 is opened allowing the level of the liquids in the container 79 to be lowered, thus inserting an increased liquid resistance between the electrodes 85 and 87 as the liquids 95 and 97, which have lower specific resistances, are progressively inserted in the circuit between electrodes 85 and 87. This movement of the bodies of conducting liquids is advantageous in that the interrupting capacity of the circuit breaker is increased due to the fact that cool portions of the liquid are continually inserted in the circuit between the electrodes. This keeps the temperature of the liquids below their boiling points, which is similar to the action of the flowing jet in the modifications shown in Figs. 1 and 2. The top of the container 79 is provided with an inlet 101 which is supplied with a gas under pressure so that the liquids are maintained at a pressure greater than that due to the atmosphere in the same manner as the modifications of the circuit interrupter shown in Fig. 3.

While several specific embodiments of the invention have been illustrated, it should be understood that various modifications can be made without departing from the spirit of the invention. It should also be understood that the various details of each of the modifications shown may be used in the other embodiments of the invention which have been illustrated without departing from the spirit of the appended claims.

We claim as our invention:

1. In a device for controlling an electric circuit, a pair of conducting members and a body of liquid for making an electrical connection therebetween, means for moving one of said conducting members out of said liquid, said movable conducting member having means for entrapping a quantity of said liquid and discharging it in a jet after said movable conducting member has been moved out of said liquid, and a nozzle of insulating material extending beyond the end of said movable conducting member for controlling the discharge of said jet.

2. In a device for controlling an electric circuit, a pair of conducting members and a body of liquid for making an electrical connection therebetween, means for moving one of said conducting members out of said liquid, said movable conducting member having a plurality of separate chambers for retaining liquid and means for causing the flow of a jet of liquid from each of said chambers in said movable conducting member when it has been moved out of the liquid, each of said jets being maintained during a period of time differing in length from those for the other jets.

3. In a circuit interrupter, a container of conducting material having a lower portion of small cross-section and an upper portion of large cross-section, a body of conducting fluid within said container, a conducting member having a cross-section slightly smaller than the lower portion of said container, means for moving said conducting member out of said container, said conducting member having means for retaining a portion of said fluid and discharging it in a jet when said movable conducting member has broken contact with the surface of said fluid, and an insulating arc barrier mounted at the surface of said fluid.

4. In a circuit interrupter, a pair of relatively movable conducting members of large area, and a body of a conducting fluid for completing a circuit therebetween, a tubular member of insulating material enclosing a portion of said body of fluid and another conducting member movable within said tubular member, and said pair of relatively movable conducting members of large area being outside of said tubular member.

5. In a circuit interrupter, a pair of relatively movable conducting members of large area, and a body of a conducting fluid for completing a circuit therebetween, a tubular member of insulating material enclosing a portion of said body of fluid and another conducting member movable within said tubular member, said pair of relatively movable conducting members of large area being outside of said tubular member, and means

for first separating said pair of relatively movable members and then withdrawing said other movable member from within the fluid enclosed by said tubular member to interrupt said circuit.

6. In a circuit interrupter, a container having a body of conducting fluid therein, a tubular member of insulating material having an opening near the bottom thereof mounted in said container and extending above the level of the fluid therein, a tubular conducting member surrounding said tubular insulator and movable out of said fluid, a conducting rod electrically connected with said tubular conducting member and movable into and out of said tubular insulating member.

7. In a device for controlling an electric circuit, a pair of conducting members and a body of liquid for making an electrical connection therebetween, means for moving one of said conducting members out of said liquid, said movable conducting member having a plurality of separate chambers for retaining said liquid and means for causing the flow of a plurality of jets of liquid from said conducting member when it has been moved out of the liquid, and one jet from each chamber being maintained during a period of time differing in length from those for the jets from the other chambers and said periods being separately determined.

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