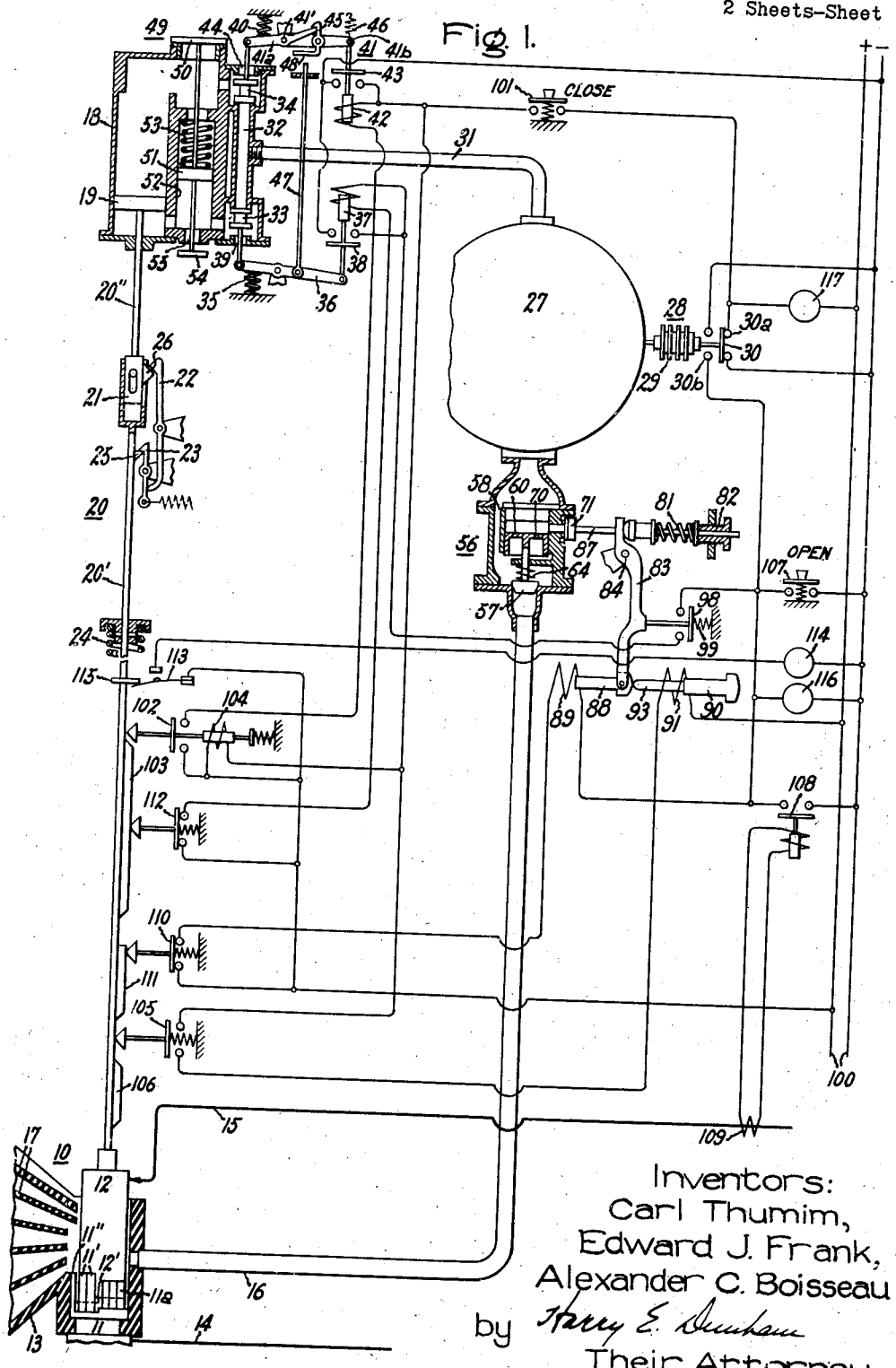
Nov. 27, 1945. C. THUMIM ET AL 2,389,942

CIRCUIT BREAKER OPERATING SYSTEM

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Fig. 1.



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Fig. 2.

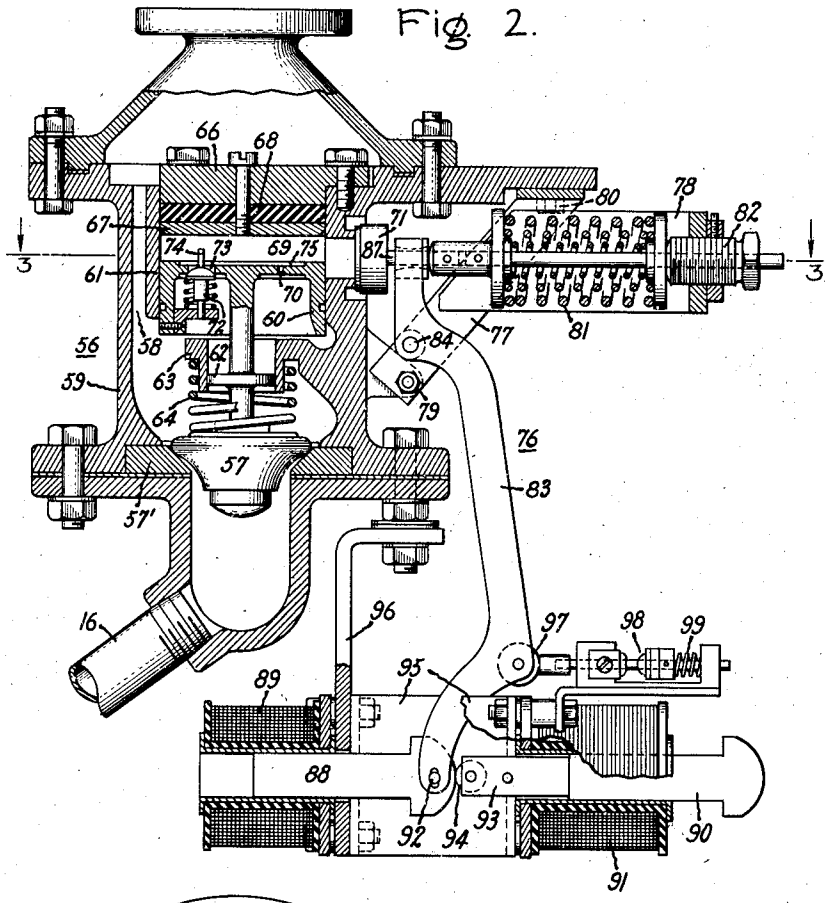
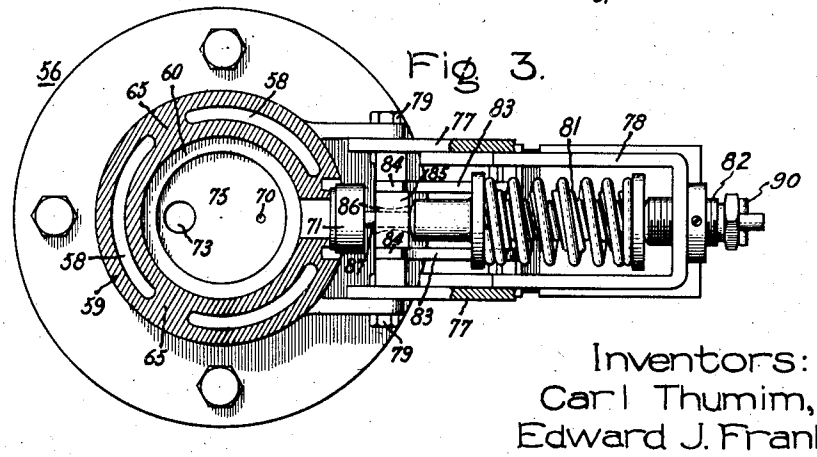


Fig. 3.



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2,389,942

CIRCUIT BREAKER OPERATING SYSTEM

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Application February 6, 1940, Serial No. 317,564

26 Claims. (Cl. 175—294)

Our invention relates to circuit-breaker operating systems and more particularly to a combined pneumatic and electrical system for effecting high-speed operation of a circuit breaker.

In order to eliminate the fire hazard, circuit breakers have been designed which do not utilize oil or other inflammable liquid for arc-extinguishing purposes but instead employ a blast of air or other gas to extinguish the arc formed both when the circuit is broken between the relatively movable contacts of the circuit breaker and also during the closing operation of the circuit breaker to prevent the formation of any arc at this time. Apart from numerous operating and structural advantages of gas-blast circuit breakers for many applications, the problem of providing a suitable control or operating system furnishes considerable difficulty.

The value of any circuit breaker lies in its ability to interrupt the circuit at the proper time and in the proper manner and, without a proper operating system for such circuit breaker, its value is largely lost since the value of the operating system lies in its ability to effect control of the circuit breaker in the manner intended. If such control is not obtained in the manner desired, many undesirable conditions may result.

It is necessary to obtain opening of the circuit breaker in as short a time as possible after the condition which initiates the opening movement occurs and this is no less true of gas-blast circuit breakers than of any other type. In order to produce the gas-blast, a valve must be operated releasing the fluid under pressure at the proper instant. To operate such a valve directly against the fluid pressure would require considerable force and, in addition, would tend to slow down the operating cycle of the circuit breaker. Balanced pressure valves have been proposed for this purpose, wherein a pilot valve requiring relatively little force to operate, unbalances the pressure on a piston-operated valve so that the fluid pressure forces the blast valve open. The balanced pressure valves of the prior art did not operate with the speed desired for high-speed circuit breaker operation and gas-blast circuit breaker operating systems employing balanced pressure valves were not as satisfactory as might be desired. We have provided a new and improved operating system for gas-blast circuit breakers including a balanced pressure type of blast valve which operates at a much higher speed than the balanced pressure valves of the prior art.

Accordingly, it is an object of our invention to provide a new and improved operating system for a circuit breaker overcoming the disadvantages above noted and wherein rapid, positive, and efficient high-speed interruption may be obtained combined with reliability, economy, and low first cost.

It is another object of our invention to provide an operating system for an electric circuit breaker of the gas-blast type in which higher speed of operation may be obtained than was heretofore possible.

It is a further object of our invention to provide a new and improved operating system for an electric circuit breaker of the gas-blast type wherein a blast of fluid for arc-extinguishing purposes is insured prior to the initiation of any opening movement of said circuit breaker.

A further object of our invention is to provide a fluid-operated gas-blast circuit breaker in which trip-free operation is provided at any time during the operating cycle of the circuit breaker.

Still another object of our invention is to provide an operating system for a fluid-operated gas-blast circuit breaker wherein energy-storage means charged during the circuit-closing operation are provided to increase the speed with which the circuit breaker may be opened.

Still another object of our invention is to provide a new and improved blast valve for the operating system of the circuit breaker.

Further objects and advantages of our invention will become apparent as the following description proceeds and the features of novelty which characterize our invention will be pointed out with particularity in the claims annexed to and forming part of this specification.

For a better understanding of our invention, reference may be had to the accompanying drawings in which Fig. 1 is a partly diagrammatic layout of an operating system for a fluid-operated gas-blast circuit breaker embodying our invention, Fig. 2 is a cross-sectional view of the blast valve shown schematically in Fig. 1, and Fig. 3 is a sectional view of the blast valve taken on line 3—3 of Fig. 2.

Referring now to the drawings, we have illustrated our invention as applied to a fluid-operated circuit breaker 10 of the cross gas-blast type comprising a stationary contact 11 and a movable contact 12 arranged to be operated so as to draw an arc in an arc chute 13. The fixed contact 11 is connected to the line terminal 14 while the movable contact 12 is connected to the line terminal 15. The fixed contact 11 is provided with spring pressed contact fingers 11a and longer arc-

ing contact fingers 11' while movable contact 12 is provided with an arcing tip 12' so that, when the contacts separate, an arc therebetween occurs between arcing tips 11' and 12'. Immediately after separation of the contacts, one terminal of the arc is transferred by an air or gas-blast through conduit 16 from contact fingers 11' to the contact 11'' which is provided with a tip of arc-resistant metal. The air or gas blast from conduit 16 upon opening of the breaker drives the arc into the arc chute 13 against the edges of a plurality of partitions 17 in the arc chute, which partitions are transverse to the arc gap and the ends of which extend close to the path of movement of the arcing tip 12' of the movable contact 12. The circuit breaker 10, illustrated by way of example in order to describe the operating system better, is not our invention but is described and claimed in the joint application of David C. Prince, William K. Rankin, and Wilfred F. Skeats, Serial No. 303,126, filed November 6, 1939, now Patent 2,284,842, and assigned to the same assignee as the present application.

In order to produce relative movement between contacts 11 and 12 by fluid pressure, we provide a fluid-operated motor comprising a cylinder 18 and a piston 19 operatively connected to movable contact 12 by means of connecting rod 20. This connecting rod 20 comprises two parts 20' and 20'' joined with one another by a lost-motion connection 21 arranged to operate a tripping means 22 for releasing latch 23 which holds the circuit breaker 10 in the closed position. For high-speed opening of circuit breaker 10, it is desirable to release some form of energy-storage means to aid the fluid pressure in the opening operation. Latch 23 is provided in order to hold energy-storage means 24 comprising a spring in the charged condition. This energy-storage means or spring 24 is charged or compressed by fluid pressure during the closing movement of circuit breaker 10 and latch 23 cooperating with member 25 restrains the circuit breaker and energy-storage means 24 in the closed and charged positions respectively until upward movement of piston 19 causes member 26 of lost-motion connection 21 to engage with tripping means 22 whereby latch 23 is released.

In order to operate piston 19 and, consequently, also movable contact 12 in response to fluid pressure, we provide a reserve fluid-pressure tank 27 which is connected to a fluid-pressure supply system through a nonreturn valve, not shown, so as to trap sufficient fluid which, for example, may be air, at a suitable pressure to permit at least one operating cycle independent of the main fluid-pressure supply. Therefore, if the main fluid air supply should fail for any reason, one operating cycle of circuit breaker 10 may still be obtained by virtue of the air or other fluid trapped in reserve tank 27. Reserve tank 27 is provided with a pressure switch, indicated schematically at 28 as comprising a Sylphon bellows 29 connected to the reserve tank 27 and operatively connected to a suitable double-throw switch 30 cooperating with a plurality of contacts 30*a* and 30*b* which will be described hereinafter in greater detail.

Fluid-pressure tank 27 is connected by means of a conduit to a manifold 32 from which the fluid pressure may be admitted to either end of cylinder 18 in accordance with the operation of either circuit breaker opening valve 33 or circuit breaker closing valve 34. Opening valve 33 is normally held in the position indicated in Fig. 1, closing one end of manifold 32 against the fluid pressure from conduit 31 by means of a relatively heavy spring 35 acting on lever 36 associated with opening valve 33. Valve 33 is arranged to be operated by opening solenoid 37, which also operates its own seal-in switch 38. Opening valve 33 in its open position is adapted to close escape port 39 through which fluid below piston 19 may escape during the closing operation of the circuit breaker 10.

Similarly, closing valve 34 is normally held in the position indicated in Fig. 1, closing the other end of manifold 32 against the fluid pressure from conduit 31 by means of a relatively heavy spring 40 acting on lever 41 associated with closing valve 34. Lever 41, however, comprises two parts 41*a* and 41*b*, both mounted on a fixed pivot 41', and, hence, differs from lever 36 associated with opening valve 33 in a manner which will be described in greater detail hereinafter. Closing valve 34 is arranged to be operated by closing solenoid 42 which also operates its own seal-in switch 43. Closing valve 34 in its open position is adapted to close escape port 44 through which fluid above piston 19 may escape during the opening operation of circuit breaker 10.

Trip-free operation of circuit breaker 10 is obtained by virtue of the fact that lever 41 associated with closing valve 34 and closing solenoid 42 is constructed of two parts 41*a* and 41*b* which are held together as a single lever by means of latch 45 pivotally mounted on member 41*b* and adapted to engage with an extension on member 41*a*. A relatively light spring 46 is provided to bias member 41*b* in such a direction that latch 45 may engage the extension on member 41*a*. It will be understood, of course, that suitable spring means will be provided for latch 45 so as normally to tend to rotate it in a counterclockwise direction to engage with the extension of member 41*a*. By the arrangement just described, lever 41 acts as a unitary member when closing solenoid 42 is energized to open closing valve 34 and, hence, to cause closing of the circuit breaker 10. If, however, during the closing operation of the circuit breaker, opening solenoid 37 should be energized through any cause, such, for example, as an abnormal current condition in the power circuits 14 and 15, opening valve 33 will be operated. In order to obtain rapid closing of closing valve 34 under such conditions and, hence, trip-free operation of the circuit breaker, rod 47 associated with opening lever 36 is provided which will engage a projection 48 on latch 45, thereby releasing lever 41*a* and allowing spring 40 to close valve 34 rapidly even though closing solenoid 42 is still energized and holding lever 41*b* downwardly against the tension of relatively light spring 46.

It is evident that the reversal of the direction of piston 19 during the trip-free closing stroke can be greatly expedited if the back pressure on the closing or upper end of piston 19 is reduced instantaneously to a practicable minimum. Accordingly, we provide between the openings in cylinder 18 and the respective opening and closing valves 33 and 34 a dumping valve 49 which is arranged to provide a very large opening to atmosphere for the upper end of cylinder 18 during the opening operation of circuit breaker 10. This dumping valve 49 comprises a relatively large valve member 50 operatively connected to a piston 51 of the same or larger diameter, reciprocable in a cylinder 52 and normally biased by means of spring 53 to hold dumping valve

member 50 in the closed position. Operatively connected with piston 51 is a second valve member 54 associated with escape port 55 which is normally open when dumping valve member 50 is closed so as to allow air or fluid from the lower end of cylinder 18 to escape to atmosphere in the same manner as port 39 and, in addition thereto, during the closing movement of circuit breaker 10. During the closing stroke of circuit breaker 10, the back pressure in the lower end of cylinder 18 without escape port 55 might build up sufficiently high to lift dumping valve member 50 from its seat with the resultant slowing up of the closing movement, since port 39 may not be sufficiently large under certain conditions to prevent this undesirable condition. When closing valve 34 is opened, the pressures operating on piston 51 and valve member 50 are substantially equal or the resultant force tends to hold valve member 50 closed, which force is supplemented by that of spring member 53. On the other hand, when opening valve 33 is operated, fluid pressure from manifold 32 operating against the relatively large surface of piston 51 overcomes the force of spring 53 and moves the entire valve assembly upwardly so as to open dumping valve member 50 and valve member 54 closes the escape port 55. By this arrangement, the upper end of cylinder 18 has the pressure therein instantaneously reduced so that rapid opening operation of circuit breaker 10 may be obtained.

The cross gas blast for arc-extinguishing purposes in arc chute 13 is also obtained from reserve fluid-pressure tank 27 through blast valve 56 and conduit 16. Blast valve 56 of the balanced pressure type, shown in detail in Figs. 2 and 3, is illustrated as mounted directly below reserve pressure tank 27 and comprises a streamlined valve member 57 which allows fluid pressure from tank 27 to pass through annular passageway 58 to conduit 16 leading to arc chute 13. Conduit 16 is illustrated in Fig. 2 as mounted at an angle with respect to blast valve 56 in order to provide additional space for illustrating the details of the control mechanism therefor. Valve member 57 cooperates with a replaceable valve seat 57' which is mounted in a casing 59 enclosing a cylinder 61 within which piston 60 operatively connected to valve member 57 reciprocates. Piston 60 is preferably flexibly connected with valve member 57 for the purpose of self-alignment and is provided with a valve guide 62 reciprocating in a sleevelike member 63. A spring member 64 is placed between sleeve member 63 and valve member 57 normally to tend to hold said valve member in the closed position. Cylinder 61, sleevelike member 63, and spring member 64 are supported centrally by radial ribs 65 bridging across annular air passage 58.

The upper end of cylinder 61 is closed by a plate 66 to which is fastened a metallic striking plate 67. Between the metallic striking plate 67 and plate 66 is a flexible buffer disk 68 to cushion the opening of blast valve 56. The space 69 in cylinder 61 between piston 60 and striking plate 67 is maintained at the absolute minimum determined only by the space required for opening valve 57 as will be set forth in greater detail hereinafter. A small passage 70 is provided in piston 60 to interconnect the cylinder 61 on either side of piston 60 and, hence, to balance the pressures operating on the upper and lower surfaces under steady-state conditions. The area of piston 60 is relatively large compared to the area of valve member 57 so that a considerably lower pressure operating on piston 60 may overcome a higher pressure operating on valve member 57.

In order to open blast valve 56, a pilot valve 71 of relatively large diameter is opened, rapidly releasing the pressure on the upper side of piston 60, whereby an unbalance of the pressure on piston 60 is obtained and the fluid pressure operating against the under side of piston 60 is sufficient to overcome the forces holding valve member 57 closed, which comprise the fluid pressure acting on the back of valve member 57 and spring means 64. Thereupon valve member 57 is forced open rapidly and piston 60 contacts with striking plate 67 whereupon check valve 72 closing port 73 in piston 60 is opened by virtue of the extension 74 thereon which engages with striking plate 67. The upper surface of piston 60 is recessed at 75 so that fluid pressure either through small passage 70 or port 73 within which check valve 72 operates is distributed over the entire upper surface of piston 60.

The time of opening of valve 57 is dependent upon the rate of pressure drop in space 69 which, in turn, is a function of the volume of space 69 and the area of pilot valve 71. In the balanced pressure valves of the prior art, the volume of space 69 was necessarily large to accommodate the biasing spring which was contained in this space. By eliminating spring 64 from space 69, it has been possible to greatly decrease the volume of space 69 determined only by the clearance necessary for valve member 57. Furthermore, the area of pilot valve 71 has been made as large as practicable and this combination has enabled us to obtain an operating speed much higher than was possible heretofore.

Check valve 72 is provided so that pressure in space 69 may be built up rapidly when pilot valve 71 is closed so that valve member 57 is snapped shut in a minimum period of time. The extension 74 on check valve 72 is sufficiently long so that check valve 72 is maintained in the open position for a reasonable length of time to prevent fluttering of the valve member 57.

It will be understood by those skilled in the art that operation of pilot valve 71 requires considerably less operating force than would be required to open blast valve 57 directly. The pilot valve 71 and operating mechanism 76 therefor are mounted as a complete constructional unit in U-shaped frame members 77 and 78 which are bolted at 79 and 80 respectively to casing 59. Pilot valve 71 is held in the closed position by means of spring mechanism 81 supported by U-shaped member 78 and including adjustable means 82 by which the closing force on pilot valve 71 may be adjusted to just overcome the normal fluid pressure in space 69 tending to open the pilot valve 71. Movement of pilot valve 71 against the force of spring mechanism 81 is effected through a pair of levers 83 pivotally mounted at 84 to U-shaped member 77 and interconnected by block 85 provided with an opening 86 through which rod 87 for operating pilot valve 71 is connected. This opening 86 in block 85 is enlarged at either end thereof so as to prevent any binding action between rod 87 and block 85 during the pivotal movement of levers 83. Pivotal movement of levers 83 is obtained either by the leftward pull of armature 88 of opening air blast solenoid 89 or by the leftward thrust of armature 90 of closing air blast solenoid 91. Pivotally mounted levers 83 are connected in clevislike fashion to armature 88 at 92 while an extension 93 provided with a roller 94 is connected

to armature 90 of closing air blast solenoid 91 so that movement of armature 90 may be transmitted through roller 94 and armature 88 to pivotally mounted members 83 for operating pilot valve 71. Solenoids 89 and 91 are coaxially mounted and connected to one another by means of U-shaped plates 95. The entire apparatus including solenoids 89 and 91 is supported from casing 59 as a unitary structure by member 96.

Pivotally mounted levers 83 are provided with a roller 97 which tends to hold a switch 98 in the open position whenever pilot valve 71 is closed. The contacts of switch 98, however, are biased to the closed position by spring means 99 so that, whenever the opening air blast solenoid 89 is energized, switch 98 is closed after which opening operation of the circuit breaker 10 is initiated. By this arrangement, switch 98 insures that the opening air blast for circuit breaker 10 is provided before opening of the circuit breaker may take place.

Certain features of our invention disclosed in this application relating to blast valve 56 per se are described and claimed in a copending application, Serial No. 345,810, filed July 16, 1940, which application is a division of this application.

In order to control the operation of opening valve 33, closing valve 34, and blast valve 56, we provide an electrical control system including a source of direct-current potential 100. This source of control potential is connected to closing solenoid 42 through pressure switch 30, contacts 30*a*, "close" button 101, and mechanically operated cut-off switch 102 which is arranged to be closed by cam member 103 when circuit breaker 10 is open and which opens at the end of the closing stroke of circuit breaker 10. Switch 102 for mechanically cutting off solenoid closing coil 42 is provided with a holding coil 104 for preventing pumping of the circuit breaker 10 in the event that it is closed upon an abnormal current condition and the operator fails to release close button 101. At a predetermined point in the closing stroke of circuit breaker 10, switch 105 which is open in both the closed and open positions of the circuit breaker is closed by virtue of cam member 106 mounted on connecting rod 20 whereby closing air blast solenoid 91 is energized for producing a blast of arc-extinguishing fluid in arc chute 13 by virtue of the movement of armature 90 which operates pilot valve 71 and, hence, also valve member 57 of blast valve 56. Mechanically operated switch 105 for controlling the closing air blast is closed before contacts 11 and 12 meet and opens after the contacts have engaged. As has been mentioned before, closing solenoid 42 is provided with a seal-in switch 43 so that the operator may release "close" button 101 prior to the completion of the closing operation.

Tripping operation of the circuit breaker may be initiated in one of three ways, either by manual operation of "open" button 107, by automatic closure of protective relay 108 which is energized from current transformer 109 associated with power line 15 whenever an abnormal current condition occurs therein, or by the bridging of contacts 30*b* of pressure relay switch 30 in the event the pressure in reserve tank 27 falls below a predetermined minimum. All three of these tripping means are connected in parallel with one another but, in any event, opening solenoid 37 cannot be energized until switch 98 has been closed which is accomplished by the operation of protective relay 108, manually operable "open" button 107, or pressure relay 28 through the energization of opening air blast solenoid 89 through mechanically cutoff switch 110. This switch 110 opens during the opening stroke of the circuit breaker 10 by virtue of cam 111 attached to connecting rod 20 and cuts off the opening air blast at the proper moment after the arc drawn has been extinguished. As soon as opening air blast solenoid 89 is energized, switch 98 is closed and opening solenoid 37 is energized through mechanical cut-off switch 112 which is closed at the beginning of the closing stroke by virtue of cam 103 mounted on connecting rod 20 and opens at the end of the opening stroke of circuit breaker 10. As was mentioned above, opening solenoid 37 is provided with a seal-in switch 38 to insure completion of the tripping operation even though "open" button 107, protective relay 108 or pressure responsive relay 28 bridging contacts 30*b* are immediately opened.

An auxiliary switch 113 is provided in series with signal means 114 which, for example, may comprise a green light to indicate that the circuit breaker is in the open position. Switch 113 is closed when circuit breaker 10 is open and is opened mechanically by means of cam 115 on connecting rod 20 when circuit breaker 10 is in the closed position. A signal means 116 which, for example, may comprise a red light is provided and is energized through opening air blast solenoid 89 and mechanically operated cut-off switch 110 for opening air blast solenoid 89 when the circuit breaker 10 is in a closed position. It will be understood by those skilled in the art that the resistance of signal means 116 is such as to allow only a very small current to flow through this circuit which is insufficient to cause solenoid 89 to pull armature 88 to the left and, hence, initiate tripping of circuit breaker 10. A signal means 117 is also provided in series with relay switch 30 and contacts 30*a* to indicate the condition of the fluid pressure in reserve tank 27. If, for any reason, the pressure in reserve tank 27 should fall below a predetermined amount, Sylphon bellows 29 will contract opening contacts 30*a* so that closing of the circuit breaker if it is in the open position is prevented. Furthermore, closing of contacts 30*b* will energize the opening air blast coil 89 and initiate tripping operation of the circuit breaker in the event that it is in the closed position.

Although we have described our invention as applied to a single-pole circuit breaker, it will be understood by those skilled in the art that it may equally well be applied to a multiple circuit breaker in which case blast valve 56 would be connected to a suitable manifold to distribute the fluid pressure to the different arc chutes of the multipole circuit breaker and connecting rod 20 would be adapted to operate a plurality of poles instead of only a single one.

The operation of our invention will be described with reference to Fig. 1 when the circuit breaker 10 is in the closed position as indicated. Tripping operation of the circuit breaker may be initiated in one of three ways; namely, if the operator manually depresses "open" button 107, if an abnormal current condition occurs in power line 15 causing energization of protective relay 108, or if the pressure in reserve pressure tank 27 decreases sufficiently so that pressure relay 28 causes switch 30 to bridge contacts 30*b*. If either of these three situations occur, opening blast solenoid 89 is energized from control circuit 100 through mechanical cut-off switch 110, thus pulling armature 88 there-

of to the left and opening pilot valve 71 as is evident from Fig. 2. The opening of pilot valve 71 will allow the pressure in space 69 to decrease rapidly so that the pressure balance on piston 60 is disturbed and valve 57 is opened, allowing a blast of fluid from tank 27 to pass through conduit 16 into arc chute 13. This fluid blast occurs before the initiation of the opening operation of circuit breaker 10. As soon as opening blast solenoid 89 is energized and armature 88 is pulled to the left, switch 98 is closed, allowing opening valve solenoid 37 to be energized both to close its seal-in switch 38 and to open opening valve 33 while closing escape port 39. This allows fluid under pressure from tank 27 and manifold 32 to enter the lower end of cylinder 18. Furthermore, this fluid pressure moves piston 51 of dumping valve 49 upwardly to close escape port 55 and provide a very large opening to atmosphere at the upper end of cylinder 18 so that high-speed opening of circuit breaker 10 may take place. The initial upward movement of piston 18 by virtue of lost-motion connection 21 causes member 26 to engage tripping means 22, whereby latch 23 is released from member 25 and energy-storage means 24 is released to aid the fluid-pressure means in high-speed opening of circuit breaker 10. As the circuit breaker 10 reaches a predetermined position in the opening stroke, a cut-off switch 110 is opened, thereby deenergizing opening air blast solenoid 89 whereby pilot valve 71 is closed by spring means 81 and check valve 72 allows fluid pressure to enter space 69 and cause valve member 57 to snap to the closed position. Further movement in the opening direction of connecting rod 20 causes cut-off switch 112 to open the energization circuit of solenoid 37, whereby opening valve 33 is forced shut by relatively heavy spring 35. Auxiliary switch 113 is allowed to close and energize signal means 114 for indicating that the circuit breaker is in the open position.

To close the circuit breaker when it is in the open position, "close" button 101 is operated and, if the pressure in tank 27 is sufficiently high so that pressure relay 28 allows switch 30 to bridge contacts 30*a*, closing solenoid 42 is energized through mechanically operated cut-off switch 102, which is in the closed position when circuit breaker 10 is open. The energization of closing solenoid 42 causes seal-in switch 43 to close and, furthermore, causes opening of closing valve 34 and closing of escape port 44 against the force of relatively heavy spring 40. This allows fluid under pressure from manifold 32 to enter the upper end of cylinder 18. Since the area of piston 51 is at least as large as that of valve member 50 of dumping valve 49, valve member 50 is maintained in the closed position by the force of spring 53 and piston 19 is forced downwardly, charging energy-storage means 24 and moving circuit breaker 10 to the closed position. Fluid underneath piston 19 is allowed to exit to atmosphere through escape ports 39 and 55. At a predetermined point prior to the meeting of contact tips 11' and 12', cut-off switch 105 for closing air blast solenoid 91 is closed, whereby armature 90 is moved to the left opening pilot valve 71 and operating blast valve 56 in the manner described above to produce a blast of gas or air transverse of contacts 11 and 12 prior to the closing thereof. After contacts 11 and 12 have engaged one another, cut-off switch 105 is opened, deenergizing closing air blast solenoid 91 and, hence, allowing spring means 81 to close pilot valve 71, whereby blast valve 56 is closed cutting off the air blast to arc chute 13 through conduit 60. Similarly, cut-off switch 104 for closing solenoid 42 is opened, whereby closing solenoid 42 is deenergized and relatively heavy spring 40 forces closing valve 34 to close manifold 32. At the same time, latch 23 engages with member 25 and tripping means 22 is reset to maintain energy-storage means 24 in a charged condition and, furthermore, hold circuit breaker 10 in the closed position. Auxiliary switch 113 is opened, deenergizing signal means 114 and signal means 116 is energized through opening air blast solenoid 89 and cut-off switch 110 therefor which has been closed as the circuit breaker reaches the closed position.

The trip-free operation of the circuit breaker will be understood by those skilled in the art in view of the detailed description given above and will only be briefly mentioned hereinafter. If during the closing operation of the circuit breaker described in the preceding paragraph, protective relay 108 should initiate a tripping operation which it may do as soon as mechanical cut-off switch 110 is closed, the tripping operation described above will be initiated and energization of opening solenoid 37 will occur, whereby lever 36 causes rod 47 to engage projection 48 of latch 45 allowing member 41*a* to pivot and close closing valve 34 by virtue of relatively heavy spring 40 even though solenoid 42 is still energized. Hence, trip-free operation is obtained and rapid opening of circuit breaker 10 is accomplished.

It will be apparent to those skilled in the art that our invention is not limited to the particular construction shown but that changes and modifications may be made without departing from the spirit and scope of our invention and we aim in the appended claims to cover all such changes and modifications.

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

1. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, a source of fluid under pressure, means operable by said fluid under pressure for producing relative movement between said contacts, a solenoid-operated valve for connecting said source of fluid with said last-mentioned means for opening said circuit breaker, a second solenoid-operated valve for connecting said source of fluid with said last-mentioned means for closing said circuit breaker, and means associated with said first-mentioned solenoid-operated valve for causing trip-free operation of said circuit breaker in the event that said circuit breaker is closed on an abnormal current condition.

2. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, a fluid motor for producing relative movement between said contacts, a source of fluid under pressure for operating said motor, a first valve for connecting said source of fluid with said fluid motor for closing said circuit breaker, a second valve for connecting said source of fluid with said fluid motor for opening said circuit breaker, said valves being so constructed and arranged as to control exhaust ports associated with said fluid motor, solenoid means for operating each of said valves, and means associated with said first valve and operable by means associated with said second valve for causing trip-free operation of said circuit

breaker even though said solenoid means associated with said first valve is energized to connect said fluid source with said fluid motor to close said circuit breaker.

3. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, a fluid motor for producing relative movement between said contacts, a source of fluid under pressure for operating said motor, a valve for connecting said source of fluid with said fluid motor for closing said circuit breaker, said valve being so constructed and arranged as to control an exhaust port associated with said fluid motor, means for operating said valve to close said circuit breaker, means for causing opening movement of said circuit breaker, and means associated with said valve for causing trip-free operation of said circuit breaker in the event that said circuit breaker is closed upon an abnormal current condition.

4. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, a fluid motor for producing relative movement between said contacts, a source of fluid under pressure for operating said motor, a first valve for connecting said source of fluid with said fluid motor for closing said circuit breaker, a second valve for connecting said source of fluid with said fluid motor for opening said circuit breaker, solenoid means for operating each of said valves, a lever interconnecting said valves with its associated operating solenoid, spring means tending to hold said valves in the closed position so as to disconnect said source of fluid from said fluid motor, said lever associated with said first valve being bifurcated and provided with a latching means to hold it as a unitary structure when said associated solenoid is energized to open said first valve, and means associated with said second valve operating on said bifurcated lever for causing said first valve to close even though its associated solenoid is still energized, whereby trip-free operation of the circuit breaker may be obtained.

5. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, a fluid motor for producing relative movement between said contacts, a source of fluid under pressure for operating said motor, valve means for selectively interconnecting said source of fluid and said motor for producing relative movement between said contacts, energy-storage means arranged to be charged during the closing stroke of said circuit breaker, restraining means for holding said circuit breaker in the closed position and said energy-storage means in the charged condition, a lost-motion connection between said fluid motor and one of said relatively movable contacts including a tripping means for releasing said energy-storage means when said fluid motor is operated to open said circuit breaker, whereby high-speed opening of said circuit breaker is obtained.

6. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, a fluid motor for producing relative movement between said contacts, a source of fluid under pressure for operating said motor, means for interconnecting said source of fluid and said motor for closing said circuit breaker, energy-storage means for opening said circuit breaker so constructed and arranged as to be charged during the closing stroke of said circuit breaker, means for restraining said energy-storage means in the charged condition when said circuit breaker is in the closed position, tripping means for releasing said energy-storage means to open said circuit breaker whereby high-speed opening of said circuit breaker is obtained, means for producing a blast of fluid for arc-extinguishing purposes during the opening operation of said circuit breaker, and means for preventing the release of said energy-storage means until said last-mentioned means is operative to produce said arc extinguishing fluid blast.

7. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, a fluid-motor for producing relative movement between said contacts, a source of fluid under pressure for operating said motor, solenoid operated valve means for connecting said source of fluid with said fluid motor for opening said circuit breaker, means including a blast valve for producing a blast of fluid adjacent said contacts for arc-extinguishing purposes, means for operating said blast valve to produce a blast of fluid adjacent said contacts upon initiation of the opening operation of said circuit breaker, and means dependent upon the operation of said blast valve for causing operation of said solenoid-operated valve to connect said source of fluid with said fluid motor to open said circuit breaker.

8. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts associated with a chamber, a fluid motor for producing relative movement between said contacts, a source of fluid under pressure, valve means for selectively interconnecting said source of fluid and said motor for opening or closing said circuit breaker, means including a blast valve for interconnecting said source of fluid and said chamber so that said contacts may be surrounded with a blast of said fluid under pressure for arc-extinguishing purposes, means for operating said blast valve prior to the initiation of the opening movement of said circuit breaker, and means for operating said blast valve to produce a blast of fluid at said contacts at a predetermined point in the closing stroke of said circuit breaker.

9. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, a fluid motor for producing relative movement between said contacts, a source of fluid under pressure for operating said motor, valve means for selectively interconnecting said source of fluid and said motor for opening or closing said circuit breaker, means including a blast valve associated with said source for producing a blast of fluid adjacent said contacts for arc-extinguishing purposes, said blast valve comprising a piston having the pressure on either side thereof balanced when said blast valve is in the closed position, and solenoid-operated means including a pilot valve for unbalancing the pressure on said piston to cause opening movement of said valve to produce a fluid blast adjacent said contacts, means for operating said blast valve prior to the opening movement of said circuit breaker, and means for operating said blast valve at a predetermined point in the closing stroke of said circuit breaker.

10. In an operating system for an electric circuit breaker of the fluid-blast type comprising a plurality of relatively movable contacts, means for producing relative movement between said contacts, a source of fluid under pressure, valve means associated with said source for producing a blast of fluid adjacent said contacts during

both opening and closing movements of said relatively movable contacts, and means for operating said valve means for a period of time during the circuit-interrupting operation of said circuit breaker which is independent of the period of time that said valve means is operated during the circuit-closing operation.

11. In an operating system for an electric circuit breaker of the fluid-blast type comprising a plurality of relatively movable contacts, means for producing relative movement between said contacts, a source of fluid under pressure, valve means associated with said source for producing a blast of fluid adjacent said contacts during both opening and closing movements of said relatively movable contacts, means for opening said valve means for a period of time during the circuit-interrupting operation of said circuit breaker which is independent of the period of time that said valve means is open during the circuit-closing operation, and means for initiating the operation of said first-mentioned means only after the operation of said valve means.

12. In an operating system for an electric circuit breaker of the fluid-blast type comprising a plurality of relatively movable contacts, means for producing relative movement between said contacts, a source of fluid under pressure, means including a valve associated with said source for producing a blast of fluid adjacent said contacts for arc-extinguishing purposes during both opening and closing movements of said circuit breaker, means for initiating the opening of said valve prior to the opening movement of said circuit breaker, and means responsive to the opening movement of said circuit breaker for determining the closing instant of said valve.

13. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, means for producing relative movement between said contacts, a source of fluid under pressure, means including a valve associated with said source for producing a blast of fluid adjacent said contacts for arc-extinguishing purposes during both opening and closing movements of said circuit breaker, means for opening said valve in response to an abnormal current condition on the power circuit associated with said circuit breaker prior to any opening movement of said circuit breaker, and means for maintaining said valve in the open position until a predetermined separation of said relatively movable contacts has occurred.

14. In an operating system for an electric circuit breaker of the fluid-blast type comprising a plurality of relatively movable contacts, means for producing relative movement between said contacts, a source of fluid under pressure, means including a valve associated with said source for producing a blast of fluid adjacent said contacts for arc-extinguishing purposes during both opening and closing movements of said circuit breaker, means for initiating the opening of said valve prior to the opening movement of said circuit breaker, cam means responsive to the opening movement of said circuit breaker for determining the closing instant of said valve, and independent cam means for controlling the operation of said valve during the closing operation of said circuit breaker.

15. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, means for producing relative movements between said contacts to open said circuit breaker, a source of fluid under pressure, means including a blast valve associated with said source for producing a blast of fluid adjacent said contacts for arc-extinguishing purposes during the opening movement of said circuit breaker, and fluid-operated means for initiating the opening movement of said circuit breaker only after a predetermined opening movement of said blast valve.

16. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, means for producing relative movement between said contacts, a source of fluid under pressure, means including a valve associated with said source for producing a blast of fluid adjacent said contacts for arc-extinguishing purposes during both opening and closing movements of said circuit breaker, means for opening said valve in response to an abnormal current condition on the power circuit associated with said circuit breaker prior to any opening movement of said circuit breaker, fluid-operated means for initiating the opening of said circuit breaker after a predetermined opening movement of said valve, and means for maintaining said valve in the open position until a predetermined separation of said relatively movable contacts has occurred.

17. In an operating system for an electric circuit breaker of the fluid-blast type comprising a plurality of relatively movable contacts, means for producing relative movement between said contacts, a source of fluid under pressure, means including a valve associated with said source for producing a blast of fluid adjacent said contacts for arc-extinguishing purposes during both opening and closing movements of said circuit breaker, a plurality of means for operating said valve prior to any opening movement of said circuit breaker, fluid-operated means for initiating the opening movement of said circuit breaker only after a predetermined opening of said valve has occurred, and means responsive to the opening movement of said circuit breaker for determining the closing instant of said valve.

18. In an operating system for an electric circuit breaker comprising a plurality of relatively movable contacts, means for producing relative movement between said contacts, means for holding said contacts in current-conducting engagement when said circuit breaker is in the closed position, fluid-operated means for releasing said last-mentioned means so that said first-mentioned means may cause opening movement of said circuit breaker, a source of fluid under pressure, means associated with said source for producing a blast of fluid adjacent said contacts for arc-extinguishing purposes during the opening movement of said circuit breaker, and means for operating said fluid-operated means only after a predetermined operation of said last-mentioned means to insure a blast of arc-extinguishing fluid adjacent said contacts upon separation thereof.

19. In an operating system for an electric switch comprising a plurality of relatively movable contacts, motive means for producing relative movement between said contacts, restraining means for holding said switch in a predetermined position, and means interposed between said motive means and one of said relatively movable contacts including a tripping means for rendering said restraining means ineffective in response to initial operation of said motive means to permit relative movement between said contacts to occur.

20. In an operating system for an electric

switch comprising a plurality of relatively movable contacts, motive means for producing relative movement between said contacts, restraining means for holding said switch in the closed position, and a lost-motion connection between said motive means and one of said relatively movable contacts including a tripping means for rendering said restraining means ineffective when said motive means is operated to produce relative movement between said contacts.

21. In a gas blast circuit breaker, separable contacts for establishing an arc, a source of gas under pressure, means for directing a blast of gas from said source against the arc to extinguish the arc, operating means actuated by gas under pressure from said source for moving said contacts to closed position, means for positively mechanically holding said contacts in the closed position, and said holding means being operated mechanically by the pressure of said source for releasing said contact means to move to open position with the pressure from said source for releasing the holding means applied prior to the application of force to the moving contact tending to move it in opening direction.

22. In a circuit interrupter, separable contacts for establishing an arc, a source of gas under pressure, operating means actuated by gas under pressure from said source for moving said contacts to closed position, mechanical means for rigidly holding said contacts in the closed position, and means operated by gas pressure applied thereto from said source prior to the application of force to said contacts tending to separate them for mechanically releasing said holding means and permitting movement of the contacts to open position.

23. In a circuit interrupter, separable contacts for establishing an arc, a source of gas under pressure, operating means including a piston actuated by gas under pressure from said source for moving said contacts to closed position when pressure is applied to one side of said piston and for moving said contacts to open position when pressure is applied to the other side of said piston, mechanical means operable automatically upon said contacts reaching closed position for rigidly holding said contacts in the closed position against any force applied to the contacts tending to move them to open position, and means operated by the gas pressure admitted from said source to the opening side of the piston for automatically mechanically releasing said holding means and permitting movement of the contacts to open position by the gas pressure admitted to the opening side of the piston, and said means acting to begin the release of the holding means prior to the application of force to the contacts tending to move them in the opening direction.

24. In a circuit interrupter of the fluid blast type, separable contact structure for establishing an arc, fluid pressure actuated means for operating said contact structure, operating valve means controlling the supply of fluid under pressure to said operating means, blast valve means for controlling the supply of arc extinguishing fluid to said contacts, and means dependent upon the position of said blast valve means for controlling the operativeness of said operating valve means controlling the supply of fluid to said operating means.

25. In a circuit interrupter of the fluid blast type, separable contact structure for establishing an arc, operating means for moving said contact structure to open and closed positions, said operating means including a fluid actuated piston, an opening valve for controlling the supply of fluid to one side of said piston for opening said contact structure, a closing valve for controlling the supply of fluid to the other side of said piston to close said contact structure, a blast valve for controlling the supply of an extinguishing fluid to said contact structure, and means interlocking said opening valve and said blast valve for maintaining said opening valve closed until said blast valve is moved toward its open position.

26. In a circuit interrupter, separable contact structure, operating means for moving said contact structure to open and closed positions, said operating means including fluid actuated piston means, opening valve means for controlling the supply of fluid to one side of said piston means for opening said contact structure, closing valve means for controlling the supply of fluid to the other side of said piston means for closing said contact structure, and means responsive to the actuation of said opening valve means to the open position for holding said closing valve means in the closed position.

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