Sept. 23, 1952 L. M. APPLEGATE 2,611,846

CIRCUIT BREAKER

Filed March 7, 1949

Fig 1

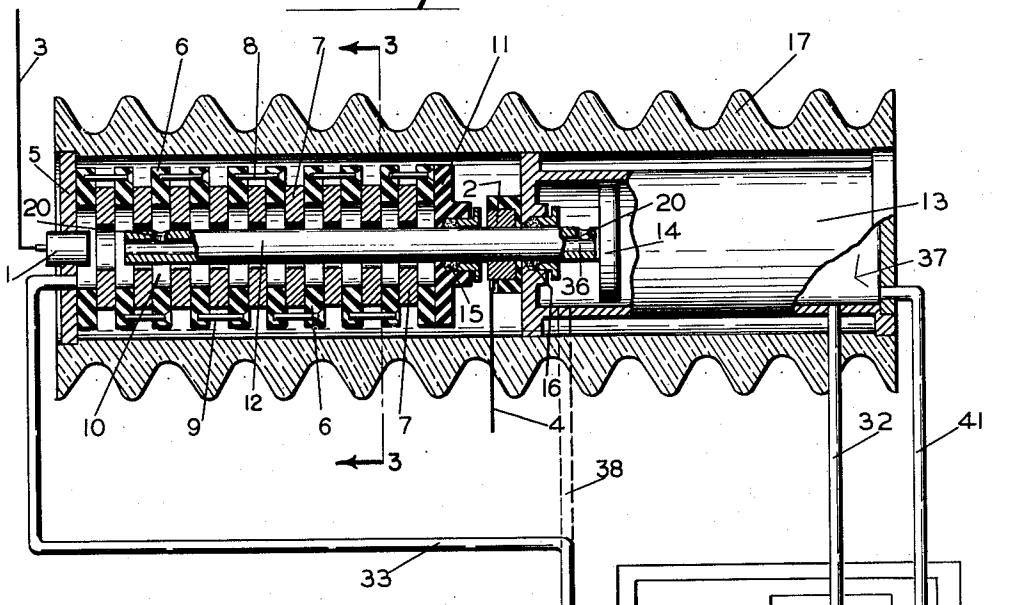
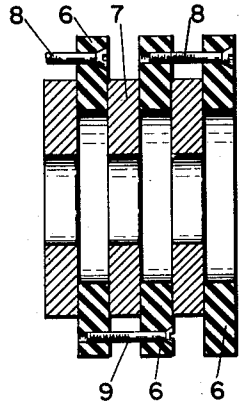


Fig 2



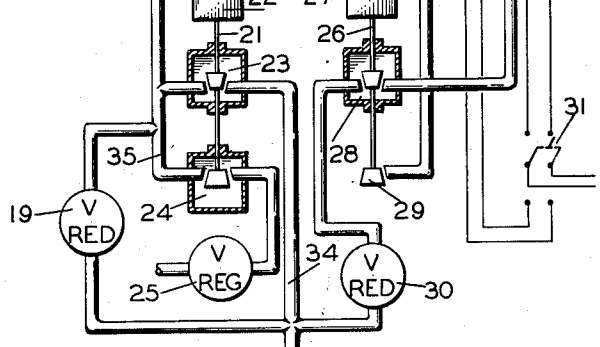
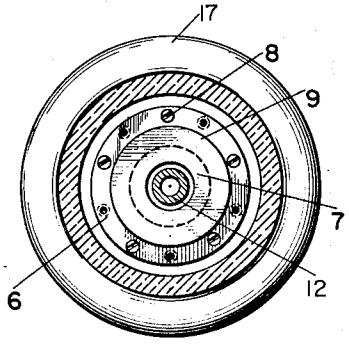
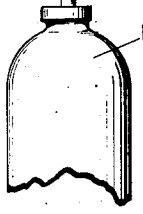


Fig 3





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Patented Sept. 23, 1952 2,611,846

UNITED STATES PATENT OFFICE

2,611,846

CIRCUIT BREAKER

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Application March 7, 1949, Serial No. 80,051

9 Claims. (Cl. 200—144)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

1

The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes without the payment to me of any royalty thereon in accordance with the provisions of the act of April 30, 1928 (Ch. 460, 45 Stat. L. 467).

This invention relates to circuit breakers intended for interrupting currents in high voltage transmission systems. It is well known in this art that the dielectric strengths of gases increase with pressure. This is applied in existing circuit breakers by confining arcs in oil-filled chambers wherein the arc produces gas by heating the oil thus developing pressures of the order of 100 atmospheres for short periods of time to assist in quenching the arc and interrupting the current. In other circuit breakers air under pressure of the order of 10 atmospheres is directed through or on contacts while being separated for the combined purposes of cooling the arc, blowing away ionized gas and increasing dielectric strength of the arc path. It is known also in this art that extinguishing arcs in circuit breakers is facilitated by the use of heavy metal parts capable of conducting heat away from the arc thus assisting in deionizing the gases near the surface of the metal. Another principle known and used in this art is that of rapidly opening the arcing gap to build up, as rapidly as possible, the dielectric strength of the arc path in the circuit breaker. In addition, the number and variety of kinds of operating mechanism in circuit breakers include pneumatic, as well as spring, motor, solenoid and other motivating systems. These fundamentals of circuit breaker construction have been applied in many different ways, and although some of these same fundamental principles are used in my present invention, the way they are applied in this instance accomplishes some useful objects in a novel way.

The principal object of my present invention is to produce a high voltage circuit breaker of simple construction for fast current interruption. Another object is to produce a circuit breaker of this kind within relatively compact dimensions. A third object is to produce a good circuit breaker for high voltage that does not have to use either oil or large volumes of gas for arc quenching.

What constitutes this, my present invention, is shown in the accompanying drawing, described in the specification following and is succinctly defined in the appended claims.

In the drawing Figure 1 is a general schematic longitudinal view of the invention in a

2

preferred form of embodiment. Figure 2 is a sectional detail of a part of the structure shown in Figure 1. Figure 3 is a view along the axis of Figure 2.

In Figure 1, there are terminals 1 and 2 connected to the circuit to be controlled by the circuit breaker by conductors 3 and 4. Terminal 1, referred to for convenience as the bottom terminal, is sealed into a terminal or base plate 5. Attached to plate 5 there is a series of insulating annular discs 6 (referred to also as annuli) and conducting annular discs 7. These discs are fastened together by bolts 8 and 9 to form a gas-tight hollow cylindrical chamber designated in its entirety as chamber 10.

At the upper end of chamber 10 there is a closure 11 through which a plunger or rod 12 enters the cylinder. Rod 12 is of highly conducting metal and is arranged to make contact with terminal 1 when in the closed position. Rod 12 slides through terminal 2 which is arranged to permit movement of rod 12 and to carry the current appropriate to the rating of the circuit breaker.

Rod 12 is arranged to move longitudinally to and from terminal 1 approximately through the full length of chamber 10. Actuation of rod 12 may be by any convenient mechanical arrangement, one preferred being a pneumatic cylinder 13 and piston 14 attached to rod 12. Clearance between rod 12 and annular discs 7 is provided so that, allowing for the usual inaccuracies of manufacture and of ordinary deflections in operation, rod 12 will not touch discs 7. This requirement is not a fundamental one inasmuch as electrically rod 12 could slide on discs 7 without any change in operational principle. If, in circuit breakers requiring long travel of rod 12, it be desired to operate rod 12 in contact with discs 7, provision should be made for smooth operation avoiding damage to the edges of discs 7 by rod 12 hitting the discs in closing. To avoid this, rod 12 should be slightly rounded at the periphery at the end.

Where rod 12 enters chamber 10, a seal or stuffing box 15 is provided to prevent excessive gas leakage. Similarly where rod 12 enters cylinder 13 there is a seal or stuffing box 16. Either or both of these seals may be omitted under some arrangements of construction, none of which are vital to the principles of operation of the circuit breaker. One variation of construction is to combine terminal 2 and one or the other of seals 15 or 16 to serve the dual purpose of contact and seal. These variations, however, are matters of

design. Rod 12 is drilled longitudinally to provide a central conduit 36 with lateral openings 20 at each end.

The assemblage of chamber 10 and cylinder 13 together with the other parts is enclosed in a cylindrical porcelain insulator 17 to protect the assemblage from the weather and to maintain a high degree of insulation over the outside of chamber 10 and to provide mechanical support. The space between chamber 10 and insulator 17 may be filled with an insulating compound such as oil to further provide for good insulation. The space between chamber 10 and insulator 17 is not necessarily under pressure, inasmuch as the pressure is generally confined to the interior of chamber 10 and cylinder 13.

Connected with chamber 10 and cylinder 13 there is a source of high-pressure gas, preferably hydrogen at pressures of 100 atmospheres or more represented by gas container 18. This may be an ordinary tank of commercially compressed hydrogen or of other commercially available gases, or a locally pumped supply of compressed air.

Container 18 is connected to chamber 10 and cylinder 13 through an assemblage of valves and electrically non-conducting tubing subject to considerable variation in arrangement. In the arrangement shown in Figure 1, gas from container 18 is admitted to chamber 10 through two paths in parallel. The first path is through a regulating valve 19 which normally holds a prescribed pressure inside chamber 10. The second path is through a magnetically operated valve 21 including an operating coil 22, an inlet valve 23 and an outlet valve 24. Connected to outlet valve 24 there is a second regulating valve 25.

Container 18 is connected to cylinder 13 through a magnetically operated valve 26 including an operating coil 27, an inlet valve 28, and an outlet valve 29. Inlet valve 28 is connected to container 18 through a regulating valve 30.

Valves 21 and 26 are interlocked so that one is open when the other is closed. This can be done in any convenient way, one of which is accomplished by a double-throw switch 31. In the up position of the switch 31 the circuit breaker is opening and in the down position the circuit breaker is closing.

Figures 2 and 3 show the structural detail of the discs 6 and 7 together with bolts 8 and 9 for providing a gas-tight chamber 10. Disc 6 is made of mechanically strong dielectric material such as vulcanized fibre or Bakelite. Disc 7 is made of a metal, preferably of good heat conductivity such as copper. Disc 7 has a concentric hole somewhat larger than the diameter of rod 12. Disc 6 has a concentric hole considerably larger than the hole in disc 7, and also a plurality of bolt holes as indicated in Figure 3. Bolts 8 and 9 are put alternately in the positions indicated in Figure 3 so that there is no continuous bolt connection along chamber 10. Countersunk flat head bolts threaded into the mating discs 6 are preferred to provide maximum clearance.

The dimensions of discs 6 and 7 are determined to a large extent by the voltage and power of the circuit to be broken. For example if the normal current to be carried by the circuit breaker is 1,000 amperes, the diameter of rod 12 will be of the order of 3 centimeters. The thickness of discs 6 is preferably in excess of the probable double dimensions of beads or projections produced on the edges of discs 7 by the heat of the arc inside chamber 10. The thickness of discs 6 is determined primarily by strength requirements. For example, if the rod 12 is 3 centimeters in diameter, the diameter of the hole in disc 7, allowing for necessary mechanical clearance, is of the order of 4 centimeters. This makes the outer diameter of discs 7, for suitable mechanical stability, of the order of 12 centimeters. Adequate space around the periphery of discs 7 for bolting in discs 6 requires in this example about 4 centimeters, making the outside diameter of discs 6 about 20 centimeters. The thickness of discs 6 for good mechanical construction in a diameter of 20 centimeters requires a thickness of the order of 2 centimeters.

Two centimeters spacing between discs 7 is, in this example, sufficient for accommodating projections due to heating at the edges of discs 7. The thickness of discs 7 should be comparable with the thickness of discs 6 to provide as much metal facing the interior of chamber 10 as practicable for the absorption of heat during the period of arcing.

The spacing of bolts in Figure 3 is illustrative only. The actual spacing needs to be small enough to avoid bending in discs 6 when chamber 10 is under pressure. The essential consideration in bolt arrangement, in addition to the necessary strength is that the bolting be rotated or staggered around discs 6 so that any one set of bolts extends across only a minimum of discs 7, preferably only two, to avoid the occurrence of more voltage than necessary between adjacent sets of bolts. This assures a high insulating value from end to end of chamber 10 since by displacing bolts 8 and 9 angularly, the total insulation along chamber 10 is practically that of air of the length of the cylinder since the spacing between adjacent bolts can be made as much as the length of the bolt.

Referring again to Figure 1, assume for purposes of explanation that the circuit breaker is closed. Rod 12 is in contact with terminal 1. Switch 31 has been closed downward thus energizing valve coil 27, opening valve 28, and closing valve 29 to the air. Regulating valve 30 holds a predetermined pressure in the right hand end of cylinder 13 through an electrically non-conducting pipe 41. Pressure on the right of piston 14 has forced rod 12 into contact with terminal 1.

Under this breaker-closed situation gas under predetermined pressure is admitted to chamber 10 through regulating valve 19 and an electrically non-conducting pipe 33. The relationship of pressure provided by regulating valves 19 and 30 is such that there will be a net difference in total pressures on the two sides of piston 14 and rod 12 that is sufficient to hold rod 12 in contact with terminal 1.

When the circuit breaker is to be opened, switch 31 is thrown to close upward energizing coil 22 of valve 21 and deenergizing coil 27 of valve 26. Valve 23 is opened admitting the full pressure of container 18 through pipes 34 and 35 to pipe 33 and to the interior of chamber 10. Regulating valve 19 is arranged with a check valve or other one-way construction to permit more than the normally regulated pressure to exist in chamber 10 when valve 23 is open. Valve 24 is closed by the action of coil 22 permitting the building up of full pressure in chamber 10. Pressure from chamber 10 is communicated to the left hand end of cylinder 13, through conduit 36 drilled lengthwise through rod 12, put-

ting more total force on the left than on the right of piston 14, causing movement to the right and separating rod 12 from terminal 1. The deenergization of coil 27 permits valve 29 to open relieving the pressure in the right hand end of cylinder 13 through an insulated pipe 32 thus leaving a maximum of pressure differential on the left of piston 14 to produce rapid acceleration and movement of rod 12 toward the right.

Rod 12 and piston 14 will arrive at the right end of cylinder 13 at high velocity. Any conventional method of damping the movement to avoid shock in stopping can be used, for example the expedient of a dashpot space at the end of the cylinder as indicated at space 37 provided by putting the connection of pipe 32 an appreciable distance from the end of cylinder 13. When the piston 14 passes the end of pipe 32, the gas in the space beyond in the end of cylinder 13 is compressed and by escape past piston 14 provides suitable deceleration and damping. A similar expedient at the left end of cylinder 13 can be used, or the pressure of the gas used for closing the circuit breaker can be limited by reducing valve 30 sufficiently to prevent unnecessarily heavy impact of rod 12 on terminal 1 in closing the circuit breaker.

When valve 23 is closed and valve 28 is opened after the circuit breaker opening just described, the high pressure that has been developed in cylinders 10 and 13 is relieved through regulating valve 25 which is set to hold a pressure somewhat greater than that maintained by regulating valve 19. This permits the pressure admitted by valve 28 and regulating valve 30 to close the circuit breaker.

There are many alternative methods of operating rod 12 and of arranging the pneumatic system. For example pressure can be admitted directly to the left end of cylinder 13 by a pipe 38, shown dotted in Figure 1. With this arrangement pressure can be communicated to chamber 10 through conduit 36 in rod 12, but this has the disadvantage of lowering the pressure somewhat in the region of the initial break at terminal 1 due to drop in pressure through the conduit 36. Another alternative arrangement is to have no communication between chamber 10 and cylinder 13, using either a regulating valve and reduced pressure or the full tank pressure of container 18 in chamber 10 and providing entirely separate connections for cylinder 13. Cylinder 13 can be operated either by the gas in container 18 or by an entirely separate source of compressed gas. The important consideration is to maintain high pressure in chamber 10 throughout the time of the circuit breaker opening and to provide sufficient differential of pressure in cylinder 13 to assure rapid movement of rod 12.

The pressure in chamber 10 can be maintained at the full pressure of container 18 continuously if adequate separate operating means are provided for activating rod 12 independently of the pressure in chamber 10. Alternatively the pressure in chamber 10 can be maintained at some lesser value or at atmospheric pressure except when the circuit is to be opened. An advantage of arrangements in which the pressure in chamber 10, when the circuit breaker is closed, remains less than the pressure when opening is that the sealing against loss of gas is not so important.

It is known in this art that the dielectric strengths of gases under high pressures are much greater than at lower pressures and further that

gases at high pressures have dielectric strengths greater than those of many insulating liquids. The increase in gas pressure develops the dielectric strength in a relatively small thickness of the gas. Accordingly pressures in chamber 10 of the order of 100 atmospheres or more are preferred. One of the important differences between my invention and the circuit breakers of the prior art is that a high pressure in the circuit interrupting chamber is provided before the contacts open. This high pressure is thus effective from the beginning of the circuit breaker opening. In the prior art high pressures in enclosed chambers resembling chamber 10 are produced by the heat developed in the arc between the contacts after they open. The suppression of the arc in such arrangements does not occur until the arc has existed long enough to develop considerable heat. When the pressure in conventional circuit breakers has developed sufficiently to interrupt the arc, the production of heat ceases and the pressure and dielectric strength of the gas decrease. In some circumstances, if in such circuit breakers the arc has been interrupted before the contacts have become much separated, additional arcs may occur, producing what are commonly referred to as "restrikes." In my invention the presence of gas under high pressure from the beginning to the end of the arc opening process causes the arc to be extinguished quickly and to minimize restrikes.

It is known also in this art that hydrogen has properties favorable for use in the presence of heat and arcing. Hydrogen avoids oxidation and corrosion due to high temperature and has the desirability of conducting heat more readily than many other gases. Accordingly hydrogen is the gas preferred for use in chamber 10. Hydrogen is preferred also because of being readily available at comparatively low cost in tanks at pressures of 100 atmospheres or more.

In the normal operation of this invention very large currents traverse the arc between terminal 1 and the end of rod 12 for short periods of time, and also through arcs between adjacent conducting annuli 7. These arcs cause some of the metal of terminal 1, rod 12, and annuli 7 to be vaporized. The vaporized metal is carried by the movement of the gas in chamber 10 to the cooler parts of the chamber where the metallic vapor is condensed to form a deposited layer of metal. In order to minimize the deposition of metal on the inner surfaces of insulating annuli 6, the difference in the diameters of the holes in annuli 6 and annuli 7 is made as much as is mechanically convenient. The projection of annuli 7 in chamber 10 appreciably within the inner radius of annuli 6, thereby presenting the maximum practicable area of exposed conducting metal surface, tends to collect a maximum amount of vaporized metal and to prevent deposition on the surfaces of annuli 6. In general in the dimensional relationship of annuli 6 and 7, the conducting annuli 7 should be as large as is feasible to provide the maximum possible amount of metal for the absorption of heat from the arc in chamber 10. The purpose of insulating annuli 6 is to provide insulation between adjacent annuli 7 and to provide the necessary mechanical strength for assembly. Accordingly annuli 6 should be restricted in internal dimensions and in thickness to a degree consistent with the minimum electrical insulation and of mechanical strength required for safe and reliable operation.

The gas that moves during the circuit breaker

opening from chamber 10 through rod 12 into cylinder 13 is subjected to heat and ionization in chamber 10 and accordingly tends to cool chamber 10. This removal of heated and ionized gas continues after the circuit breaker has been fully opened until switch 31 is opened, closing valve 23. The additional gas blown through chamber 10 and cylinder 13 does no harm and may contribute to circuit interruption but controls should be provided to prevent unnecessary waste of gas and loss of pressure in chamber 10. Conventional means for sequential control of valves are adequate for this.

In the mechanical arrangements for using this circuit breaker two units as shown in Figure 1 can be coupled together at plate 5 providing a double-break circuit breaker. Also this circuit breaker can be combined with other sets of contacts in parallel so that terminal 1 and rod 12 will carry the full circuit current only at times of circuit opening or closing. The combination of heavy current carrying contacts which open before the operation of contacts specially designed for arc interruption is already known in this art. My invention is adaptable for use in such multiple contact arrangements in place of the known arc interruping devices as well as to use in place of the ordinary oil or air circuit breakers.

I claim:

1. A high voltage circuit breaker comprising a chamber composed of a plurality of conducting annuli interspersed with insulating annuli to form a gas tight insulated cylindrical chamber, separable contacts inside said chamber, and means for maintaining gas under pressure in said chamber said conducting annuli being held between said insulating annuli which are held in compression on said conducting annuli by bolts spaced around the outside of, and separated from, said conducting annuli.

2. A high voltage circuit breaker comprising a chamber composed of conducting annuli intersperced with insulating annuli, the outside diameter of said insulating annuli being greater than that of the conducting annuli, bolts holding successive pairs of insulating annuli together, said bolts being angularly displaced around said annuli so bolts in successive pairs of annuli are insulated from each other thus providing a chamber bolted end to end in which said conducting annuli are insulated and in which the end to end insulation of said chamber is comparable with the same length in air, separable contacts in said chamber and means for maintaining gas at high pressure therein.

3. A circuit breaker comprising a cylindrical chamber composed of alternate annuli of insulating and conducting material, bolts in said insulating annuli holding them together, said bolts staggered to provide secure holding without objectionable impairment of longitudinal insulation strength over said chamber, separable contacts in said chamber and means for maintaining an atmosphere of gas at high pressure in said chamber.

4. In a circuit breaker the combination of a fixed contact, a movable contact and a pressure chamber comprising a stack of alternate conducting and insulating annuli and longitudinal bolts for holding said annuli together to provide a gas-tight chamber insulated between the ends, said conducting annuli each having a smaller external diameter than said insulating annuli, and said bolts being spaced around successive

pairs of said insulating annuli outside and separated from said conducting annuli, said spacing providing for bolts in any two successive insulating annuli being separated from bolts holding either one of the said two successive insulating annuli and any third adjacent insulating annulus so that the bolts on the two sides of any one insulating annulus are separated and insulated from each other.

5. In a circuit breaker the combination of a fixed contact, a movable contact and a pressure chamber comprising with suitable end pieces a stack of at least 5 annuli, successive annuli being alternately of conducting and of insulating materials, and longitudinal bolts for holdnig said annuli together to provide a gas-tight chamber insulated between the ends, said conducting annuli each having external diameter less than the external diameter of said insulating annuli, and said bolts being spaced radially away from said conducting annuli and spaced around inside the circumference of said insulating annuli so that the bolts holding the first two insulating annuli together are spaced apart from the bolts holding the second and third insulating annuli, thereby holding said conducting annuli tightly between adjacent insulating annuli, and maintaining insulation between the bolts on one side of any one insulating annulus and the bolts on the other side of that annulus.

6. In a circuit breaker the combination of a gas-tight cylindrical chamber insulated between its ends, a contact in one end of said chamber, a contact-making rod entering the other end of said chamber through a gas-tight opening and attached outside said chamber to a piston operating in a gas-activated cylinder, and means for admitting gas under pressure to said chamber, openings in and through said rod placed to permit a flow of gas from inside said chamber through said rod to said gas-activated cylinder, whereby the admission of gas under pressure to said chamber causes said piston to draw said contact-making rod away from said contact, thereby opening the connection between said contact and said contact-making rod.

7. In a circuit breaker the combination of a gas-tight chamber composed of alternate conducting and insulating annuli, said conducting annuli having outside radius less than that of the insulating annuli, bolts in the outer rims of said insulating annuli holding said conducting annuli in compression between adjacent insulating annuli, each bolt being spaced and insulated from adjacent bolts so the bolts on one side of any one insulating annulus are insulated from the bolts on the opposite side of the annulus, gas-tight end pieces in said chamber, a centered contact in one end of said chamber, a longitudinally movable contact-making rod entering the other end of said chamber, means for moving said rod toward or away from connection with said contact and means for introducing gas under pressure into said chamber.

8. In a circuit breaker as set forth in claim 7 the elements claimed therein, in combination with an insulating tube in which said gas-tight chamber is enclosed for the maintenance of external insulation thereon.

9. In a high-voltage circuit breaker the combination of a cylindrical chamber, concentric separable contacts therein, means for opening and closing said contacts, and means for maintaining gas at high pressure in said chamber, said chamber being made of concentric alternate

conducting and insulating annuli held tightly together by attachments to said insulating annuli, said attachments being distributed and spaced to hold all conducting annuli tightly in compression, and to have attachments holding successive conducting annuli insulated from each other.

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