Sept. 4, 1962

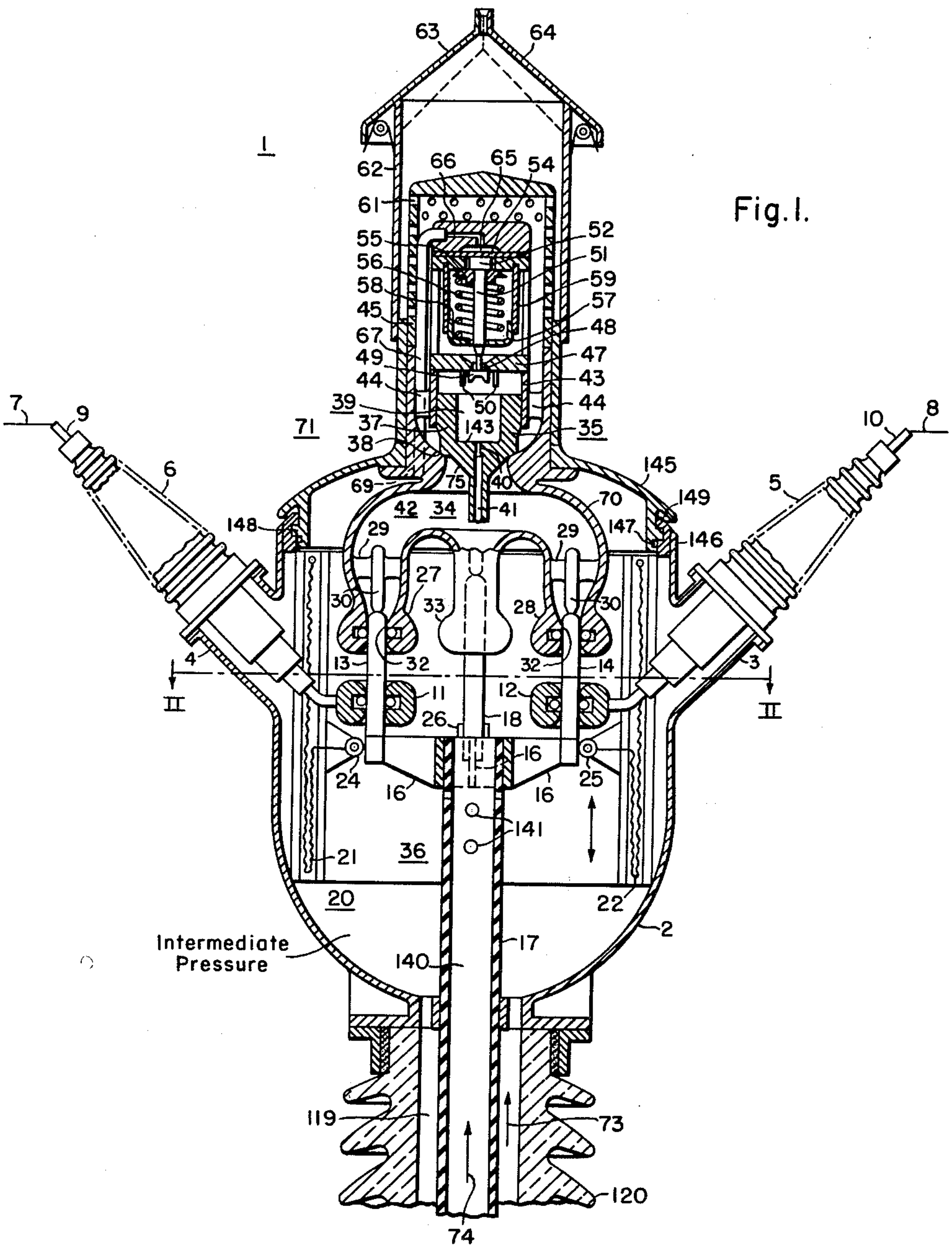
O. BURON

3,052,783

COMPRESSED-GAS CIRCUIT INTERRUPTERS

Filed June 24, 1958

4 Sheets-Sheet 1



WITNESSES

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COMPRESSED-GAS CIRCUIT INTERRUPTERS

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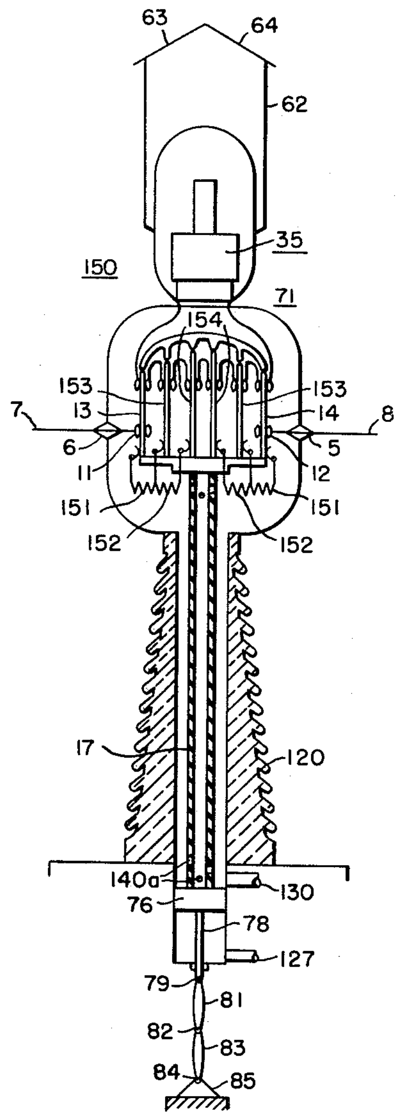

Fig. 4.

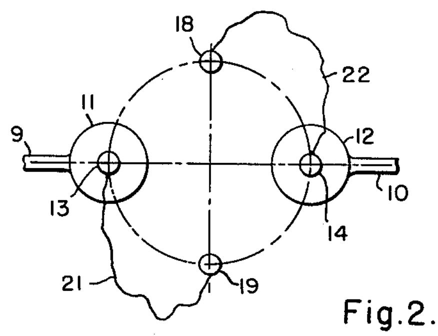

Fig. 2.

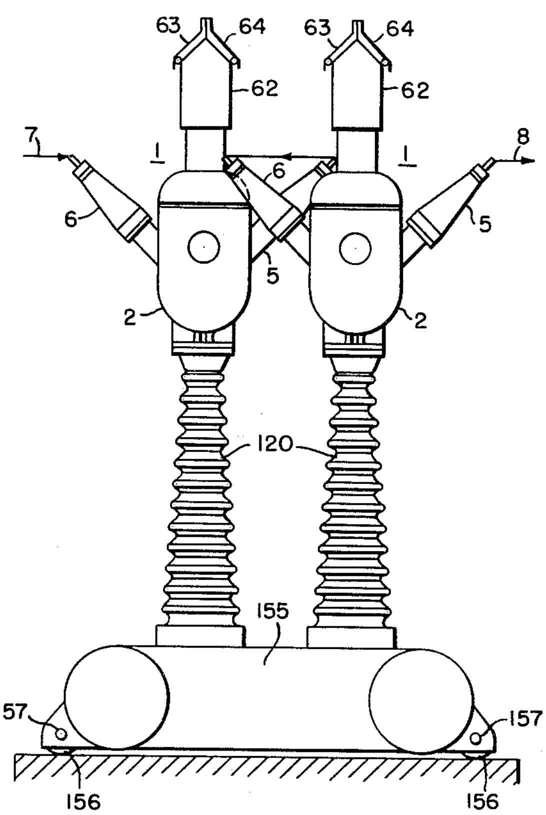

Fig. 5.

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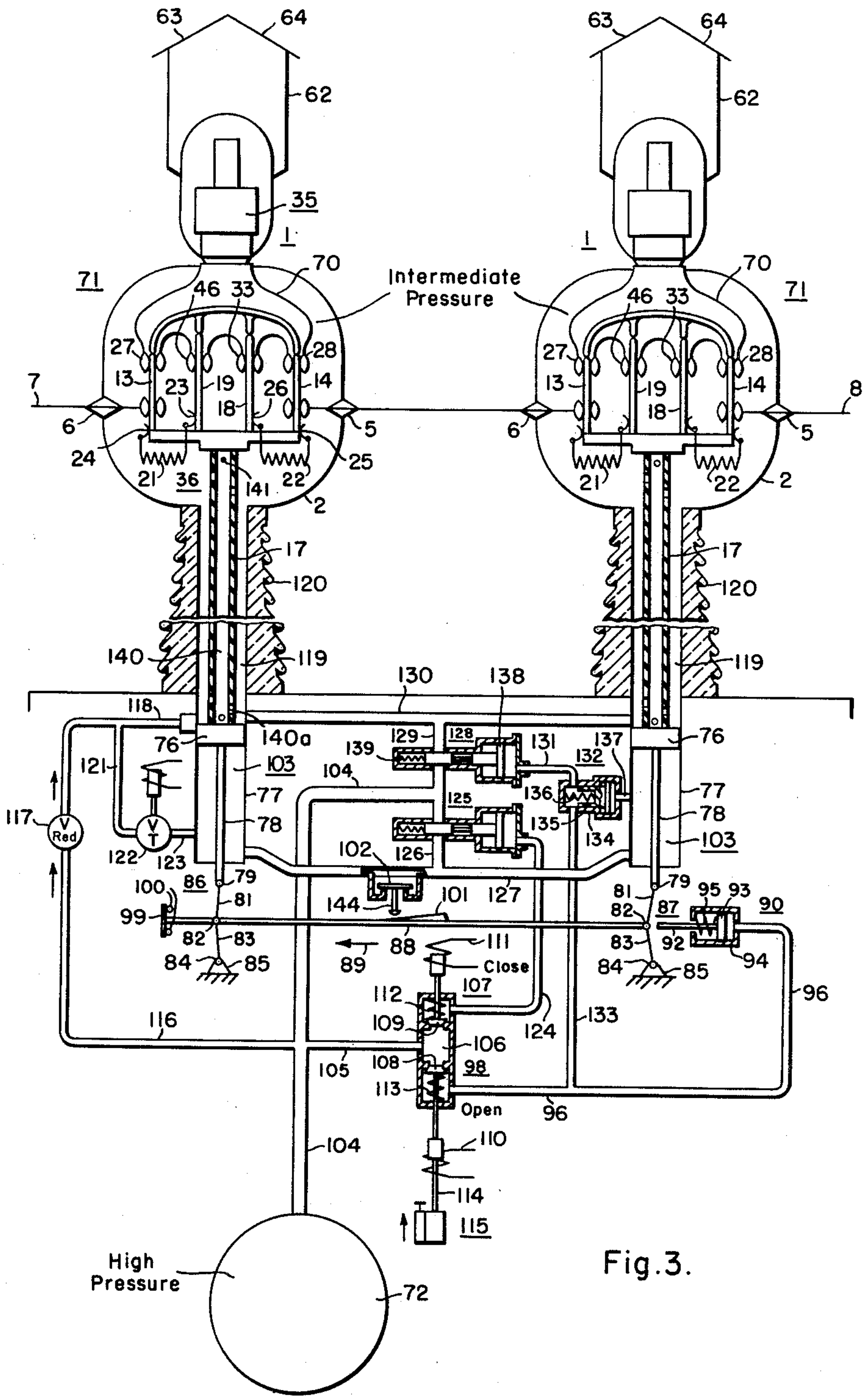

Fig. 3.

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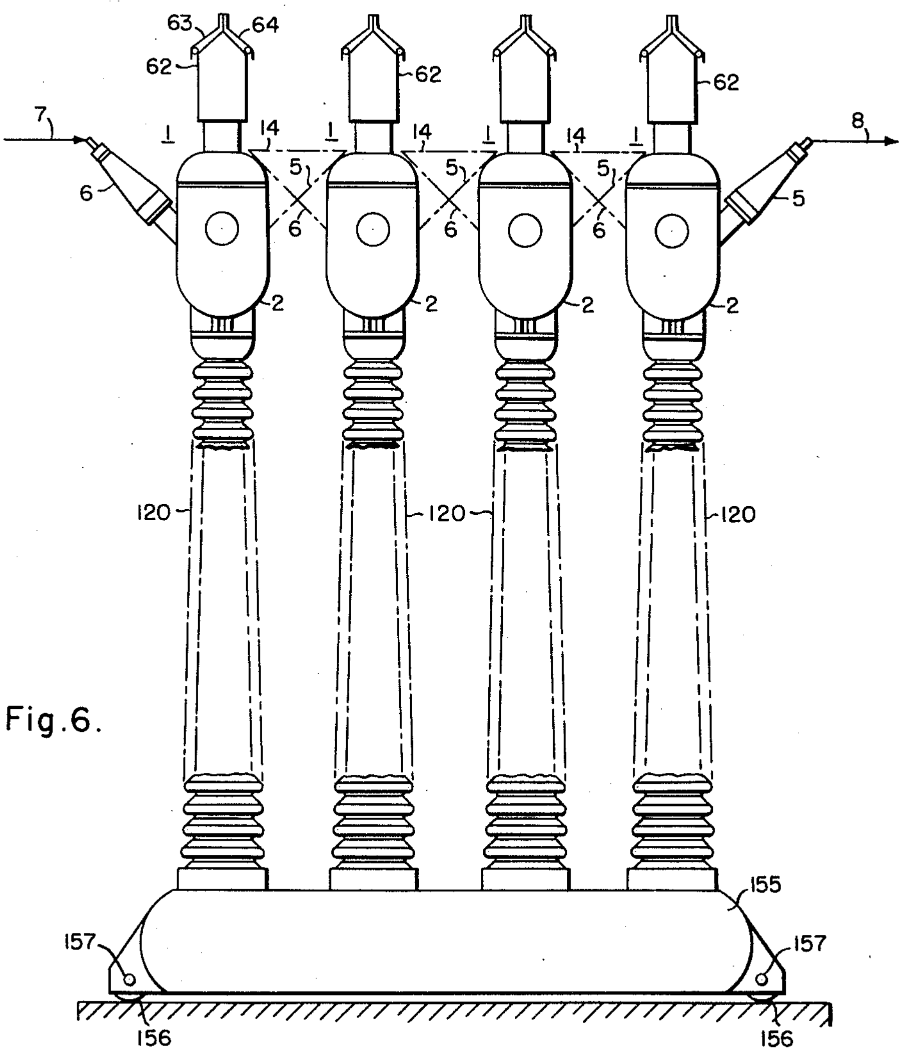
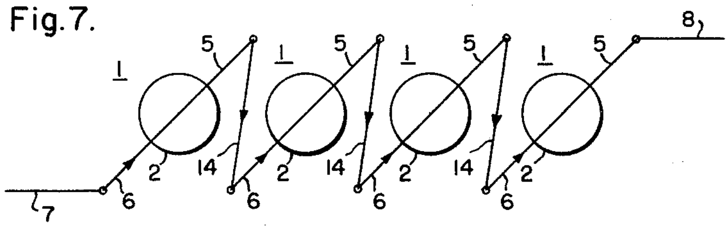


Fig.6.

Fig.7.



United States Patent Office

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3,052,783
COMPRESSED-GAS CIRCUIT INTERRUPTERS

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15 Claims. (Cl. 200—148)

This invention relates to circuit interrupters in general, and, more particularly, to arc-extinguishing structures and operating mechanisms for compressed-gas circuit interrupters.

A general object of the present invention is to provide an improved compressed-gas circuit interrupter, which will be more effective in operation than compressed-gas circuit interrupters heretofore employed in the industry.

A more specific object of the present invention is to provide an improved compressed-gas circuit interrupter in which the separating contact structure is disposed within an enclosed chamber having a substantial intermediate pressure, for example 5 atmospheres.

Another object of the invention is to provide an improved contact structure employing impedance means, such as resistances, which may be successively inserted by steps into series circuit during the opening operation.

Another object of the invention is to provide an improved contact structure involving a plurality of movable contacts, which are simultaneously actuated toward the open-circuit position, and function to insert impedance steps into the circuit. Preferably, certain of said movable contacts are of greater length than others of said movable contacts, so that the desired sequence of contact separation is achieved during the opening operation for the proper insertion of series resistance steps to facilitate arc interruption.

Another object of the invention is to provide an improved compressed-gas circuit interrupter, in which the separable contact structure is disposed within an enclosed chamber maintained under an intermediate pressure of, say 5 atmospheres, and in which an exhaust valve, permitting the exhausting of arc-extinguishing gas, is operated upon the occurrence of a higher pressure existing within said enclosed chamber which is greater than the aforesaid 5 atmospheres pressure. Thus, by the employment of the intermediate pressure, such as 5 atmospheres, it is possible, because of the increased dielectric strength of the enclosed gas, to minimize the separation distances between conducting parts at different potentials within said enclosed chamber.

A further object of the present invention is the provision of a compressed-gas circuit interrupter involving a plurality of movable contacts, in which said movable contacts are supported, and actuated, by means of a common, insulating, supporting carriage structure.

Another object of the invention is to provide an improved pneumatic operating mechanism for a compressed-gas circuit interrupter.

A further object of the present invention is to provide an improved pneumatic operating mechanism for a compressed-gas circuit interrupter, in which the speed of opening movement of the movable contacts may be controlled, or regulated, at all times during the opening operation.

Yet a further object of the present invention is to provide an improved pneumatic operating mechanism for a compressed-gas circuit interrupter, in which latching means, such as a toggle arrangement, for example, is provided to latch the movable contact structure in the closed-circuit position.

Another object of the present invention is to provide an improved compressed-gas circuit interrupter, in which

only a single insulating tubular member is employed between the movable contact structure and the grounded operating mechanism to initiate opening of the movable contact structure, and, in addition, spacing the high-voltage parts from ground potential.

Another object of the invention is to provide an improved compressed-gas circuit interrupter utilizing piston means for effecting the opening operation of the contact structure, and in which control for the dump valve for exhausting gas from one side of the piston means is provided, for consequent controlling of the speed of opening movement of the interrupter.

Yet a further object of the present invention is to provide an improved pneumatic operating mechanism for a pair of serially related interrupting structures, in which simultaneous operation of both interrupting structures may be mechanically achieved by a novel interlocking arrangement.

An auxiliary object of the invention is to provide an improved pneumatic operating mechanism for a compressed-gas circuit interrupter, in which a suitable cut-off valve is provided to cut off the blast air, when the movable contact structure has arrived at a predetermined opening position, regardless of the maintenance of the opening valve in the "open" position.

Further objects and advantages will readily become apparent upon reading the following specification, taken in conjunction with the drawings, in which:

FIGURE 1 is a vertical sectional view through the enclosed interrupting chamber of a compressed-gas circuit interrupter, only fragmentarily shown, embodying principles of the present invention, with the contact structure being illustrated in the closed-circuit position;

FIGURE 2 is a somewhat diagrammatic plan view, taken substantially along the line II—II of FIGURE 1 looking in the direction of the arrows, and illustrating the disposition of the movable contact rods relative to each other;

FIGURE 3 is a somewhat diagrammatic view illustrating two serially related interrupting chambers, of the type illustrated in FIGURE 1, showing the use therewith of a pneumatic operating mechanism achieving desirable features of operation, with the contact structure being illustrated in the closed-circuit position;

FIGURE 4 is a somewhat diagrammatic view of a modified type of interrupting unit, having a plurality of impedance steps, the contact structure being illustrated in the closed-circuit position;

FIGURE 5 is a side elevational view illustrating a pair of interrupting structures disposed in series relation for the interruption of higher-voltage circuits;

FIGURE 6 is a side elevational view of a circuit interrupting assemblage involving a number of serially related interrupting structures; and,

FIGURE 7 illustrates diagrammatically, in plan view, the passage of current through a multiple-unit, compressed-gas circuit interrupter, such as shown in FIGURE 6.

Referring to the drawings, and more particularly to FIGURE 1 thereof, the reference numeral **1** generally designates a circuit interrupter including an enclosed metallic chamber **2**, which preferably is made of sheet steel. Although the enclosure **2** is preferably of metal, it may also be made of insulating material, and, in such an event, the spacing distances between component parts may be somewhat decreased.

The metallic enclosing chamber **2** has extending diametrically outwardly therefrom supporting boss portions **3**, **4** through which extend terminal bushings **5**, **6**. Transmission leads **7**, **8** may be connected to the external terminal studs **9**, **10**. If desired, the terminal bushings **5**, **6** may be of the condensor wound type, to uniformly grade the voltage gradient between the interiorly disposed terminal studs 9, 10 and the outer metallic supporting portions 3, 4.

The interior ends of the terminal studs 9, 10 terminate in stationary, sliding contacts 11, 12, which bear against movable rod-shaped contacts 13, 14. The latter are fixedly secured to insulating, radially outwardly extending supporting fins 16, jutting laterally outwardly from the upper end of an insulating, tubular, operating rod 17, adapted for vertical reciprocal motion.

Extending into, and out of, the plane of the paper of FIGURE 1 are additional insulating supporting fins 16, which serve to support auxiliary rod-shaped movable contacts 18, 19, which are of a greater length than the length of the movable contacts 13, 14, the purpose for which will appear more fully hereinafter.

Disposed interiorly within the enclosing chamber 2 is impedance means 20, in this particular instance comprising a pair of resistance sections or steps 21, 22. One end of the resistance section 21 is connected to a contact roller 24, and the other end of the resistance step 21 is connected, by a sliding contact, not shown, to the front auxiliary movable contact 19 (FIG. 2). The other resistance step 22 has one end thereof connected to a roller contact 25 bearing against the side of movable contact 14, whereas the other end of resistance step 22 is connected to a sliding contact 26 bearing against movable auxiliary contact 18.

Thus, as illustrated more clearly in FIGURE 2, a resistance section 21 is connected between the movable contacts 13, 19 and the other resistance section 22 is electrically connected between movable contacts 14, 18.

The use of roller contacts for a guiding and a contacting function is set forth and claimed in U.S. patent application, filed December 20, 1956, Serial No. 629,604, now United States Patent 2,866,045 issued December 23, 1958, to Winthrop M. Leeds, and assigned to the Westinghouse Electric Corporation.

The relatively short rod-shaped movable contacts 13, 14 extend within orifice-shaped, relatively stationary contacts 27, 28 having supported therein, by conducting, integral fins 29, centrally located arcing electrodes 30. The arcing electrodes or arc catchers 30 function to maintain the established arcs centrally within the orifice openings 32 of the orifice contacts 27, 28.

Similarly, the relatively lengthened, movable auxiliary contacts 18, 19 cooperate with orifice-shaped stationary contacts 33, 46, as illustrated in FIG. 3. All four orifice-shaped relatively stationary contacts 27, 28, 33 and 46 have associated therewith a common exhaust passage 34, for the exhausting of arc-extinguishing gas through an over-pressure valve structure, generally designated by the reference numeral 35, which is responsive to the pressure within the region 36 interiorly of the enclosing chamber 2.

The over-pressure valve structure 35 includes a self-closing, pressure responsive valve 37 making contact with a valve seat 38, as shown in FIG. 1. The region 39, above the exhaust valve 37, communicates by means of a restricted opening 40 with a passage 41, the latter communicating with the region 42 within the exhaust passage 34. The exhaust valve 37 is reciprocally guided within a fixed supporting sleeve 43. The supporting sleeve 43 is spaced by spacing fins 44, from an outer cylindrically-shaped valve casing 45.

Disposed at the upper end of the support sleeve 43 is a stationary closure plate 47, having an opening 48 therethrough, which opening 48 is controlled by a pilot valve 49. The pilot valve 49 is guided by depending lugs 50. The valve stem 51 of the pilot valve 49 has a head portion 52, which makes contact with a differential acting, pressure-responsive diaphragm 54.

The valve stem 51 of pilot valve 49 has a spring plate 55 secured thereto, which forms the upper seat for a closing, compression spring 56. As is obvious, the closing compression spring 56 tends to seat, or close, the pilot

valve 49 over the opening 48, and hence maintain the region 39 over valve 37 closed to the atmosphere and at the pressure of exhaust region 34.

The lower end of compression spring 56 seats upon a stationary, cup-shaped spring seat 57, the latter having a threaded connection, as at 58, to a stationary supporting sleeve 59. The valve casing 45 has, at its upper end, a plurality of openings 61, constituting a muffler, which opens into an outer muffler chamber 62. The upper end of the muffler chamber 62 has a pair of mating, spring-closed covers 63, 64. Normally, when the interrupter 1 is at rest, either in the open or in the closed-circuit positions, the spring-biased covers 63, 64 will assume a closed position, as is illustrated in FIG. 1.

The region 65, above the differential acting pressure responsive diaphragm 54 communicates, by way of a passage 66 and a tube 67, through an additional passage 69, provided in valve seat 38, to the region 36 within enclosure chamber 2, which normally contains an intermediate pressure, such, for example, as 5 atmospheres.

In the closed-circuit position of the interrupter 1, as illustrated in FIG. 1, the electrical circuit therethrough includes transmission line 7, terminal stud 9, stationary sliding contact 11, movable rod contact 13, stationary orifice contact 27, through the walls 70 of common exhaust outlet 34 to the diametrically positioned, opposite, orifice-shaped contact 28. The circuit then extends through movable rod-shaped contact 14, through stationary sliding contact 12 to terminal stud 10 and thence to line conductor 8. A parallel electrical path extends through the resistance steps 21, 22 and movable auxiliary contacts 18, 19, but because of the resistance, this alternate, parallel path will carry little current.

During the opening operation, the tubular insulating operating rod 17 moves downwardly, carrying therewith all four movable rod-shaped contacts 13, 14, 18, 19. Since movable contacts 13, 14, are shorter than auxiliary movable contacts 18, 19, movable contacts 13, 14 will separate first from their cooperating relatively stationary contacts 27, 28, thereby compelling the electrical circuit to traverse the two resistance sections, or steps 21, 22. More specifically, the circuit now extends through terminal stud 9, fixed sliding contact 11, movable contact 13, conducting roller 24, resistance step 21, sliding contact 23 (FIG. 3) to auxiliary movable contact 19 (FIG. 3). Since auxiliary movable contact 19 is still in engagement with orifice-shaped contact 46 (FIG. 3), the electrical circuit extends through the wall 70 of exhaust outlet 34 to the other relatively stationary orifice-shaped contact 33, thence to auxiliary movable contact 18, sliding contact 26, resistance step 22, contact roller 25, movable rod contact 14, stationary sliding contact 12, to the other terminal stud 10 associated with the other terminal bushing 5.

Thus, it will be observed that at this stage of the opening operation of interrupter 1, two steps of resistance 21, 22 are inserted serially into the electrical circuit. This will serve to reduce the current through the electrical circuit, and also will serve to improve the power factor of the circuit. Continued downward opening movement of tubular insulating operating rod 17 will ultimately cause disengagement between movable, auxiliary contacts 18, 19 and their associated stationary, orifice-shaped contacts 33, 46. This will draw two residual current arcs in series, which arcs will be quickly extinguished by the flow of compressed gas out of the region 36 within enclosing chamber 2, and through the orifices 32 of the orifice-shaped stationary contacts 33, 46 in a manner hereinafter described. Circuit interruption will thereby quickly take place.

To visualize now the flow of compressed gas which occurs during an interrupting operation, it must be remembered that initially, and while the interrupter 1 is at rest, that is in either the open or closed-circuit position, that an intermediate pressure, such as 5 atmospheres, exists within the region 36 interiorly of enclosing chamber 2. This 5 atmospheres pressure is obviously higher than the surrounding atmospheric pressure within region 71 externally of circuit interrupter 1, and it is a lesser pressure than the 15 atmospheres pressure, which is stored within high-pressure storage tank 72 (FIG. 3). Thus, during an opening operation, means, hereinafter described, effects the upward passage of high-pressure compressed gas, at 15 atmospheres pressure, for example, in the direction of the arrow 73 of FIG. 1 and also through the tubular operating rod 17, as illustrated by the arrow 74, so that very rapidly the pressure within region 36, within enclosing chamber 2, rises from 5 atmospheres to 15 atmospheres pressure. This 15 atmospheres pressure will act through passage 69, through tube 67 and through passage 66 to act within the region 65 on top of the differential acting, pressure-responsive diaphragm 54. This increased pressure within region 65 on top of differential pressure responsive diaphragm 54 will cause valve stem 51 of pilot valve 49 to move downwardly, against the spring pressure exerted by closing compression spring 56. The downward movement of pilot-valve stem 51, and hence of pilot valve 49, will cause the pilot valve 49 to open the opening 48 within closure plate 47, to permit thereby a dumping of the 5 atmospheres pressure, initially present within region 39, on top of main exhaust valve 37. This 5 atmospheres initial pressure within region 39 was caused by leakage through passage 41 and restricted opening 40 of the valve 37, because of natural leakage of the 5 atmospheres pressure around rod-shaped contacts 13, 14, 18, 19 within openings 32 of orifice contacts 27, 28, 33 and 46 to the region 42.

The dumping of the pressure within region 39 above exhaust valve 37 will permit the high-pressure gas, passing through the openings 32 and into common exhaust passage 34, to act upwardly upon the lower surface 75 of exhaust valve 37, it being remembered that at this time at least movable contacts 13, 14 have cleared the openings 32 and have hence provided a passage for the high-pressure gas, at, say 15 atmospheres pressure, to act within the common exhaust passage 34 and upwardly upon valve 37. Exhaust valve 37 will then snap open upwardly, and will permit the exhausting of high-pressure, arc-extinguishing gas through the muffler openings 61 and into the muffler chamber 62, where, because of the increased pressure, spring-biased cover plates 63, 64 will separate. The extinguishing gas will then exhaust upwardly to the atmosphere 71.

The interrupting unit 1 of FIG. 1 may, for example, be suitable for the interruption of 50,000 volts. For handling 100,000 volts, it may be necessary to employ two such interrupting units 1 in series relation, as diagrammatically indicated in FIG. 3. For purposes of clarity, the contact structure is diagrammatically indicated in a single plane to more clearly illustrate the insertion of the resistance steps 21, 22.

The longitudinally movable insulating operating tubes 17 have pistons 76 secured to their lower ends to effect the actuation thereof. The plungers, or pistons 76, are reciprocally movable vertically within operating cylinders 77. Fixedly secured to the lower end of each operating piston 76 is a piston rod 78, the lower end of which is pivotally connected, as at 79, to a toggle link 81. The toggle link 81 is pivotally connected, by a knee pin 82, to a second toggle link 83, the latter being pivotally connected, as at 84, to a fixed bracket support 85.

It will, therefore, be noted, with reference to FIG. 3, that in the closed-circuit position of the interrupter, that the contact structures of both interrupting units 1 are locked, or latched into position by the toggle linkages 86, 87. A control rod 88 is provided to mechanically interconnect the knee pivot pins 82 of the toggle linkages 86, 87, and the control rod may be moved toward a releasing position, that is to the left, as indicated by the arrow 89, upon the actuation of a pneumatically actuated release plunger, generally designated by the reference numeral 90. The release plunger 90 includes a releasing plunger rod 92 having secured thereto a piston 93, operable within a piston cylinder 94, and biased by a compression spring 95 to the right, that is, to a non-releasing position, as shown in FIG. 3. The release plunger 90 may be actuated by the admission of compressed gas through a pipe 96, which pneumatically connects the release plunger 90 to an opening control valve, generally designated by the reference numeral 98.

It will be observed that the left-hand extremity of the control rod 88 carries a conducting bridge 99, which serves to electrically bridge a pair of contacts 100, which may serve to energize an indicating circuit. Also, the control rod 88 has adjustably affixed thereto a cam 101, which, when moved to the left, serves to raise a dumping control valve 102. The dumping control valve 102 functions to dump, or to exhaust, the air pressure within the regions 103 beneath both plunger pistons 76.

It is to be noted that in order to obtain optimum interruption performance at the contact structure, the contact rods 13, 14, 18 and 19 should always move with the same predetermined speed since the interruption occurs when the current passes through the zero value.

The dump valve 102 may be controlled by means of a wedge-shaped cam 101 which is mounted for longitudinal adjustment on the control rod 88, and with its camming surface is adapted to control the operating stem of regulating valve 102. This time-controlled interruption is a result of the particular shape of cam 101 such that its camming surface will not immediately open valve 102 but only when the toggle levers 83 have already been moved to the left a certain extent, and the air underneath the plungers 76 is already correspondingly compressed. A result of the compression of the air in the operating cylinders 77 is that the contact studs 13, 14, 18, 19 have moved a certain distance, favorable for the extinction of the arcs by the compressed air, in a period of time at the end of which extinction of the arcs is definitely completed. Thereupon, valve 102 is opened so that the contact studs may rapidly move to their extreme open-circuit position. Thus, preferably the camming surface of the cam 101 has a relatively flat initial portion followed by a portion of steeper gradient, the slope in both instances corresponding to the desired operated speed.

Also, the cam 101 may be so constructed that it will close valve 102 after the interrupting operation has been completed, so as to prevent the compressed air from escaping through valve 102 upon a subsequent closing of the circuit breaker, when the control rod 88 will be moved to its right-hand extremity.

The high-pressure storage tank 72 feeds high-pressure dry compressed gas upwardly through an inlet pipe 104 and through a connecting pipe 105 into a region 106, between the opening pilot control valve 98 and a closing pilot control valve 107. The opening and closing pilot control valves 98, 107 have pilot valves 108, 109, which are electrically actuated by solenoids 110 and 111, respectively. Both pilot valves 108, 109 are biased by compression springs 112, 113 to the closed position, as illustrated in FIGURE 3. In addition, the opening pilot control valve 98 has a depending stem 114, which is mechanically connected to a time-delay control device, generally designated by the reference numeral 115. The time-delay, control device 115 may be an adjustable dash-pot, as shown, to insure that the pilot opening valve 108 will be maintained open for a sufficient length of time to insure complete arc interruption in both interrupting units 1.

A connecting pipe 116 branches laterally from inlet feed pipe 104 to a reducing valve 117, which functions to provide a constant, reduced pressure through a feed pipe 118 into the operating cylinders 77 on the upper sides of both actuating pistons 76. Since an annular passage 119 is provided within upstanding pedestals 120, the reducing valve 117 provides the aforesaid intermediate pressure, say 5 atmospheres, within the regions 36 within both interrupting casings 2.

Branching downwardly from the feed pipe 118 is an additional pipe 121, which connects into an electrically controlled throttle valve 122, which feeds gas through a pipe 123 into the regions 103 below both plunger pistons 76. Thus, there is an equalization of gas pressure on both sides of the plunger pistons 76, which pressure is constantly maintained at the aforesaid 5 atmospheres intermediate pressure when the interrupters 1 are at rest. As a consequence, there is no strain imposed upon the toggle linkages 86, 87 in the closed-circuit position of the interrupter, as illustrated in FIG. 3.

An inlet pipe 124 connects the closing control valve 107 to a main closing control spindle valve, generally designated by the reference numeral 125, and controlling the admission of gas from the main high-pressure feed pipe 104 into a pipe 126 and hence into a connecting pipe 127 leading to the lower ends of both operating cylinders 77.

A main opening control-spindle valve, generally designated by the reference numeral 128, controls the admission of high-pressure gas from the main high-pressure inlet pipe 104 into a pipe 129, connecting into an opening pipe 130, which feeds both annular passages 119, within pedestals 120, and also the top surfaces of both plunger pistons 76. The opening spindle valve 128 is connected, through a pipe 131 and through a shut-off valve, generally designated by the reference numeral 132, and by way of a branch pipe 133 to the pipe 96 leading to the opening control valve 98. Disposed interiorly within the operating cylinder 134 of the shut-off valve 132 is a cylindrical differential-piston valve 135, biased to the open position by a spring 136, as shown in FIG. 3. As shown, the right-hand end of piston valve 135 is larger than the left-hand end thereof so that equal pressures will cause leftward movement of the valve. The cylindrical valve 135 is moved to the left, against the spring pressure exerted by the compression spring 136, upon the admission of high-pressure gas through a pipe 137, when plunger piston 76 moves below pipe 137 near the end of the opening operation. Thus, even though opening valve 98 is maintained upon by time-delay device 115, nevertheless, to avoid waste of gas, the cut-off valve 132 will be operated to cut off the blast of opening gas when the contact structure is at a predetermined opening position—that is, piston 76 moving below inlet pipe 137.

By way of recapitulation, during the opening operation of the interrupter, the opening solenoid 110 is energized by any suitable means. This will open valve 108, which will remain open for a sufficient length of time for interruption by functioning of the time-delay device 115. High-pressure gas will pass from the region 106 through pipe 96 upwardly through pipe 133, through shut-off valve 132, through pipe 131 to move the opening control spindle valve 138 to the left, against spring pressure exerted by spring 139. This will permit high-pressure gas to flow from inlet pipe 104 into pipe 129 and into opening pipe 130, so that high-pressure gas is fed to the upper surfaces of both operating pistons 76.

During this time, high-pressure gas from pipe 96 is also fed into release plunger 90, forcing the plunger rod 92 toward the left, thereby moving control rod 88 toward the left, collapsing both toggle linkages 86, 87. The release, or unlocking of the toggle linkages 86, 87, permits piston rods 78 to move downwardly. Thus, the high-pressure gas acting on the top surfaces of both pistons 76, by way of opening conduit 130, forces pistons 76 downwardly within operating cylinders 77, thereby carrying downwardly therewith the tubular operating rods 17 to effect disengagement of main movable contacts 13, 14 from their cooperating nozzle-shaped contacts 27, 28. The high-pressure gas issuing from opening conduit 130 will pass upwardly through the annular passage 119 within insulating pedestal 120. It will also pass upwardly through the interior 140 of tubular operating rod 17. It will be observed that each tubular insulating operating rod 17 is provided with a plurality of apertures 140*a*, 141 at its lower and upper ends respectively, so that not only does operating rod 17 serve to actuate the movable contact structure, but also it serves as a connecting feed pipe to supply high-pressure gas to the interior 36 of the interrupting casing 2.

The aforesaid separation of the main contacts 13, 14 from their cooperating contacts 27, 28 will permit the high-pressure gas flowing into casing 2 to act upwardly through the region 42 of exhaust passage 34 and to act through pipe 67 upon the upper surface of differential control diaphragm 54, thereby moving pilot valve 49 downwardly. Because of the restriction 40, the region 39 is controlled by the opening of pilot valve 49 rather than by the admission of high-pressure gas at 15 atmospheres passing upwardly through pipe 41. Consequently, since the upper side 143 of main exhaust valve 37 is now exposed to atmospheric pressure, as caused by opening of pilot valve 49, and since high-pressure gas at 15 atmospheres acts against the lower surface 75 of main valve 37, the main exhaust valve 37 will move quickly upwardly and open, thereby permitting the upward exhausting of the arcing gases out of the exhaust passage 34 and into the muffler chamber 62.

The current passing through the interrupters 1 will be forced to pass through the resistance steps 21, 22, since the main arcs between contacts 13, 27 and 14, 28 will be quickly extinguished. Subsequently, auxiliary movable contacts 18, 19 will separate from their stationary nozzle-shaped contacts 33, 46 so that the two residual current arcs will be likewise extinguished by the exhausting of high-pressure gas out through pressure-responsive valve structure 35.

During the aforesaid lowering of plunger pistons 76 to open the movable contact structures cam 101 on control rod 88 had not yet encountered the stem 144 of dump valve 102. As a consequence of this delay, gas was compressed within the regions 103 below both actuating pistons 76, so that the speed of the opening motion of the contact structures could be controlled for most effective interruption.

Preferably, the adjustable cam 101 does not abut the stem 144 of dumping control valve 102 to exhaust regions 103 to atmosphere, until all the arcs have been extinguished. By moving the dumping control valve 102 upwardly by cam 101, and thereby exhausting the regions 103 below pistons 76 to atmosphere, there is then provided additional downward opening travel of actuating pistons 76, and operating rods 17, so that as a consequence of this additional opening movement, an isolating gap distance is provided between the several movable contacts 18, 19 and their cooperable stationary contacts 33, 46 in both interrupters 1.

Thus, the additional isolating gap distance, which occurs after arc interruption, is brought about by opening the dumping valve 102, this occurring following arc interruption.

It will be remembered that the provision of the time delay device 115 maintains opening valve 108 open for a certain time sufficient for arc interruption following energization of opening solenoid 110. To prevent waste of high-pressure gas, the shut-off valve 132 is actuated to close the passage between conduits 131, 133 when actuating piston 76 moves below the inlet pipe 137, and thereby permits high-pressure gas to flow from pipe 130, through operating cylinder 77, through pipe 137 to operate the shut-off valve 135. This will prevent unnecessary waste of high-pressure gas after the contact structure has attained a predetermined opening position, even though opening valve 98 is maintained "open" by time-delay device 115.

It will be observed that the impedance means 20, comprising the resistance steps 21, 22, is disposed in such a location within interrupting casing 2, that it will be cooled by the upward exhausting of gas through casing 2 and out through the exhaust valve 37.

It will moreover be observed that a closure cap 145 (FIG. 1) has a removable bayonet connection with the upper rim 146 of the interrupter casing 2, so that the closure cap 145 may readily be removed, thereby removing the several stationary orifice contacts 27, 28, 33 and 46 together with the entire exhaust-valve structure 35. Preferably, a ring-shaped gasket 147 is provided to insure a gas-tight connection between the mounting flange 148 of cap 145 and the inwardly extending mounting flange 149 of casing 2.

It will be observed that the exhaust gases are directed vertically upwardly out of the muffler chamber 62 through the spring-biased cover plates 63, 64 so that no torque is exerted upon the interrupter 1 straining the insulating pedestal 120, which may be made of a rather fragile material, such as porcelain. In addition, the upward exhaust of the arcing gases minimizes the noise, which is caused during an interrupting operation, as compared to arrangements where the exhaust gases are directed laterally.

FIGURE 4 illustrates a modified type of interrupting unit, generally designated by the reference numeral 150, in which four steps of resistances 151, 152 are successively inserted into series circuit by auxiliary movable contacts 153, 154. It will be observed that the movable auxiliary contact 154 is of a greater length than the movable auxiliary contact 153, the latter, in turn, being of greater length than the movable main contact 13. Thus, FIG. 4 shows an arrangement generally similar to the interrupting structure 1 of FIG. 1, except that instead of two steps of resistance 21, 22 being electrically inserted into series circuit, instead, in the arrangement of the interrupter 150 of FIG. 4, four steps of resistance are inserted into series circuit.

FIG. 5 shows how the interrupting structure of the present invention may be employed in conjunction with a second interrupting structure. FIG. 5, for example, illustrates an interrupting application of say 100,000 volts, wherein two interrupting structures 1 of the type illustrated in FIG. 3, may be made portable, as indicated by the wheels 156 mounted upon axles 157.

For particular applications, it may be necessary to employ a number of interrupting structures 1 in series. FIG. 6 illustrates an application where four interrupting chambers 1 are utilized in series electrically for the higher voltages, and FIG. 7 diagrammatically illustrates, in plan, the passage of current through such a multiple series device. Electrical connectors 14 may be employed between adjacent interrupters 1.

From the foregoing description of the invention, it will be apparent that there is provided an improved compressed-gas type of circuit interrupter, in which the movable contact structure is disposed within a relatively small, enclosing casing 2 containing gas at an intermediate pressure, say, for example, 5 atmospheres pressure. By regulating the spring pressure of the compression spring 56 associated with pilot valve 49, the intermediate pressure within the interrupting casing 2 may be varied in any manner desired. The resistance steps 21, 22 are disposed in such a location as to be effectively cooled by the exhausting of gas out of the casing 2, during an interrupting operation and the tubular interrupting operating rod 17 not only provides contact actuation, but also serves the additional function of assisting to supply high-pressure gas to the casing 2 during the interrupting operation.

Disassembly of the interrupting chamber 1 is facilitated by the removable bayonet connection between mounting flanges 148, 149 associated respectively with the cap structure 145 and with the rim 146 of casing 2. Removal of the cap structure 145 effects simultaneous removal of the stationary orifice-shaped contact structures 27, 28, 33 and 46. Unbalancing stress upon the interrupting structure 1 is avoided by directing the exhaust gases vertically upwardly.

The pneumatic control, illustrated in FIG. 3, is such as to insure simultaneous operation of both interrupting units 1 and it prevents waste of high-pressure opening gas by the employment of the shut-off valve 132 operated at a predetermined point or position in the opening stroke of the movable contact structure.

The opening speed of the movable contact structure is regulated by the use of the dumping control valve 102, which is not actuated until the arcs are interrupted; consequently, optimum interrupting performance is constantly achieved. It will be noted that the contact structures in both interrupting units 1 are locked in the closed position by the toggle linkages 86, 87, and a mechanical interconnection between the two movable contact structures is achieved by employment of the laterally movable control rod 88. The reducing valve 117 insures a constant supply of an intermediate pressure to the casings 2, and the throttle valve 122 insures a balanced pressure on both sides of the actuating pistons 76, when the interrupters 1 are at rest. Thus, no stress is imposed upon the toggle linkages 86, 87 in the closed-circuit position of the interrupting device.

By employing enclosed chambers 2 with an enclosed intermediate pressure therein, the casings 2 and consequently the interrupting structures 1 may be made smaller and more compact than conventional interrupting structures. Also, the interrupters are not subject to various atmospheric conditions, all contact parts being enclosed in dry, compressed gas of high dielectric strength.

The operating rods 17 are more reliable and accurate than a hydraulic or pneumatic control means for actuating the movable contact structure.

Although there have been illustrated and described various interrupting structures incorporating principles of the present invention, it is to be understood that the same were merely for the purpose of illustration, and that changes and modifications may readily be made therein by those skilled in the art, without departing from the spirit and scope of the invention.

I claim as my invention:

1. A compressed-gas circuit interrupter including a substantially enclosed interrupting chamber, means defining an external source of high-pressure gas, means defining an exhaust outlet for said substantially enclosed interrupting chamber, contact means separable to establish an arc within said interrupting chamber, an exhaust valve separate from said separable contact means and responsive to the pressure of the gas within said substantially enclosed interrupting chamber for opening said exhaust outlet for exhausting high-pressure gas during the opening operation of the interrupter, blast-valve means for feeding high-pressure gas from said external source of high-pressure gas into said substantially enclosed interrupting chamber during the opening operation, means including said exhaust valve for maintaining an intermediate pressure within said substantially enclosed interrupting chamber which is higher than atmospheric pressure but which is lower than the pressure at said high-pressure source, and said exhaust valve opening upon entrance of high-pressure gas into the interrupting chamber to create a flow of high pressure gas to effect extinction of the drawn arc at said separable contact means.

2. The combination in a compressed-gas circuit interrupter of a metallic substantially enclosed interrupting chamber containing a gas under an intermediate pressure which is higher than atmospheric pressure, bushing means including a pair of terminal bushings extending into said metallic enclosed interrupting chamber, separable contact structure disposed interiorly within said enclosed interrupting chamber, means electrically connecting said separable contact structure to the interior ends of said pair of terminal bushings, an exhaust valve for said

chamber separate from said separable contact structure and responsive to a predetermined high pressure therein, means for feeding high-pressure gas from an external high-pressure source into said interrupting chamber for arc extinction purposes, means for simultaneously raising the pressure within said interrupting chamber and effecting separation of said separable contact structure, and said exhaust valve opening during the opening operation of the interrupter to exhaust an arc-extinguishing blast of gas from the interrupting chamber.

3. A circuit interrupter for interrupting a single break between two serially related line connections including a plurality of relatively stationary contacts electrically connected together and to one of said line connections, a plurality of movable contacts disposed in electrically parallel relationship and of varying length, means electrically connecting the longest movable contact to the other of said line connections, means insulating the movable contacts from each other except for one or more impedance steps bridging the plurality of movable contacts of varying length, means moving the movable contacts as a unit simultaneously, whereby said one or more impedance steps will be successively inserted into said single break in parallel manner during the interrupting operation and whereby the shortest movable contact breaks the remaining residual current arc.

4. The combination of claim 3, wherein the plurality of relatively stationary contacts assume the form of nozzle-shaped contacts, and gas-blast means forces a fluid blast through the relatively stationary nozzle contacts upon separation therefrom of the cooperable movable contacts.

5. A compressed-gas circuit interrupter including an enclosed metallic chamber at line potential containing an exhaust valve operable at a predetermined pressure, a plurality of nozzle-shaped relatively stationary contacts connected to said chamber at line potential, a common exhaust outlet interconnecting all of said nozzle-shaped relatively stationary contacts, said common exhaust outlet leading to the exhaust valve, a plurality of movable electrically parallel rod-shaped contacts of varying length, one or more impedance steps connected to said rod-shaped movable contacts of varying length, means for causing simultaneous movement of said rod-shaped movable contacts, means for supplying high-pressure gas to said enclosed chamber to effect opening of said exhaust valve, and the high-pressure gas passing into said nozzle-shaped relatively stationary contacts to effect extinction of the arcs drawn thereat.

6. A compresssed-gas circuit interrupter including an enclosed chamber containing gas under an intermediate pressure higher than atmospheric pressure, an exhaust valve for venting said chamber and opened at a predetermined pressure higher than said intermediate pressure, a plurality of nozzle-shaped relatively stationary contacts, a common exhaust outlet interconnecting all of said nozzle-shaped relatively stationary contacts, said common exhaust outlet leading to the exhaust valve, a plurality of movable rod-shaped contacts of varying length, one or more impedance steps connected to said rod-shaped movable contacts of varying length, means for causing simultaneous movement of said rod-shaped movable contacts, means for suppying high-pressure gas to said enclosed chamber to effect opening of said exhaust valve, and the high-pressure gas passing into said nozzle-shaped relatively stationary contacts to effect extinction of the arcs drawn thereat.

7. The combination in a compressed-gas circuit interrupter of a high-voltage metallic enclosed chamber containing gas at an intermediate pressure which is higher than atmospheric pressure, a pair of terminal bushings extending into said metallic enclosed chamber and carrying stationary contacts at their inner ends, a pair of movable contacts disposed within said chamber, a pair of orifice-shaped relatively stationary contacts disposed within said chamber, an exhaust valve for said chamber opened at a predetermined high pressure within said chamber, a common exhaust duct for all said orifice-shaped relatively stationary contacts leading to said exhaust valve, means for feeding high-pressure gas to said chamber, and means for effecting opening movement of said movable contacts.

8. A compressed-gas circuit interrupter including at least two interrupting chambers, a separable contact structure associated with each chamber, an operating rod connected to each separable contact structure to effect the opening and closing movements thereof, a toggle linkage including a knee pin connected to each operating rod, a control rod positively connected to the knee pins of the two toggle linkages, and an actuating piston for effecting releasing breaking movement of said control rod.

9. The combination in a compressed-gas circuit interrupter of separable contact structure, an operating rod for effecting opening movement of said separable contact structure, a piston secured to said operating rod, an operating cylinder within which said piston reciprocates, a dump valve for exhausting the gas on the closing side of said piston during the opening operation, and means delaying the opening of said dump valve during the opening operation of the interrupter until a time which is near the time of arc extinction.

10. A compressed-gas circuit interrupter including a relatively movable contact cooperable with a relatively stationary contact to establish an arc, means including a main opening control valve for controlling a blast of gas toward said arc, a pilot valve for pneumatically actuating said control valve, and a cut-off valve disposed in the pneumatic line of said pilot valve and closed in accordance with a predetermined open position of the movable contact.

11. A compressed-gas circuit interrupter including a storage reservoir for the storage of high-pressure gas, movable contact structure separable to establish an arc, a main opening control valve and a main closing control valve for effecting opening and closing movements respectively of the movable contact structure, an opening pilot valve and a closing pilot valve for the aforesaid control valves, an operating cylinder, an actuating piston connected to the movable contact structure and movable within said operating cylinder, a cut-off valve disposed in the pneumatic line from said opening pilot valve to said main opening control valve, and means actuating said cut-off valve in accordance with the position of said actuating piston within said operating cylinder.

12. A compressed-gas circuit interrupter including a pair of upstanding arc-extinguishing assemblages, each arc-extinguishing assemblage including a closed chamber supported at the upper end of an insulating pedestal, separable contact structure disposed in each closed chamber, an exhaust valve for each chamber opened at a predetermined high pressure therein, an operating rod for actuating the separable contact structure within each closed chamber, an actuating piston secured to each operating rod, togggle means for locking each operating rod in the close position, and a control rod positively connecting the knee pins of the two toggle means.

13. The combination in a high-voltage compressed-gas circuit interrupter of a substantially enclosed metallic interrupting chamber, an insulating supporting column for supporting said metallic interrupting chamber up in the air above ground potential, a pair of terminal bushings extending into said metallic interrupting chamber, relatively stationary contact structure supported by and electrically connected to said metallic interrupting chamber so that the latter is at line potential, an exhaust valve at line potential separate from said relatively stationary contact structure and responsive to a predetermined pressure within said interrupting chamber to provide an exhausting blast of gas past said relatively stationary contact structure,

movable contact structure electrically connected to the inner ends of said pair of terminal bushings and separable from the relatively stationary contact structure to establish arcing, and mechanical rod means for causing opening and closing motion of said movable contact structure through said insulating supporting column.

14. A compressed-gas circuit interrupter including a substantially enclosed interrupting chamber, a plurality of nozzle-shaped relatively stationary contacts, a common exhaust outlet interconnecting all of said nozzle-shaped relatively stationary contacts, an exhaust valve for said common exhaust outlet opened upon a predetermined rise of pressure within the substantially enclosed interrupting chamber and maintaining a predetermined intermediate pressure within the interrupting chamber greater than atmospheric pressure, a plurality of cooperable rod-shaped movable contacts cooperable with said plurality of nozzle-shaped relatively stationary contacts to establish a plurality of serially related arcs, and means for feeding high-pressure gas into said interrupting chamber only during the opening operation to effect opening of said exhaust valve and extinction of said arcs.

15. A compressed-gas circuit interrupter including a substantially enclosed interrupting chamber, a plurality of nozzle-shaped relatively stationary contacts electrically connected together, a common exhaust outlet interconnecting all of said nozzle-shaped relatively stationary contacts, an exhaust valve for said common exhaust outlet opened upon a predetermined rise of pressure within the substantially enclosed interrupting chamber, a plurality of cooperable electrically parallel rod-shaped movable contacts of varying length cooperable with said plurality of nozzle-shaped relatively stationary contacts to establish a plurality of electrically parallel related arcs in sequence, means for feeding high-pressure gas into said interrupting chamber during the opening operation to effect opening of said exhaust valve and extinction of said arcs, and impedance means connected between at least a pair of said varying-length movable rod-shaped contacts, whereby the shortest movable rod-shaped contact will break the residual current arc.

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