

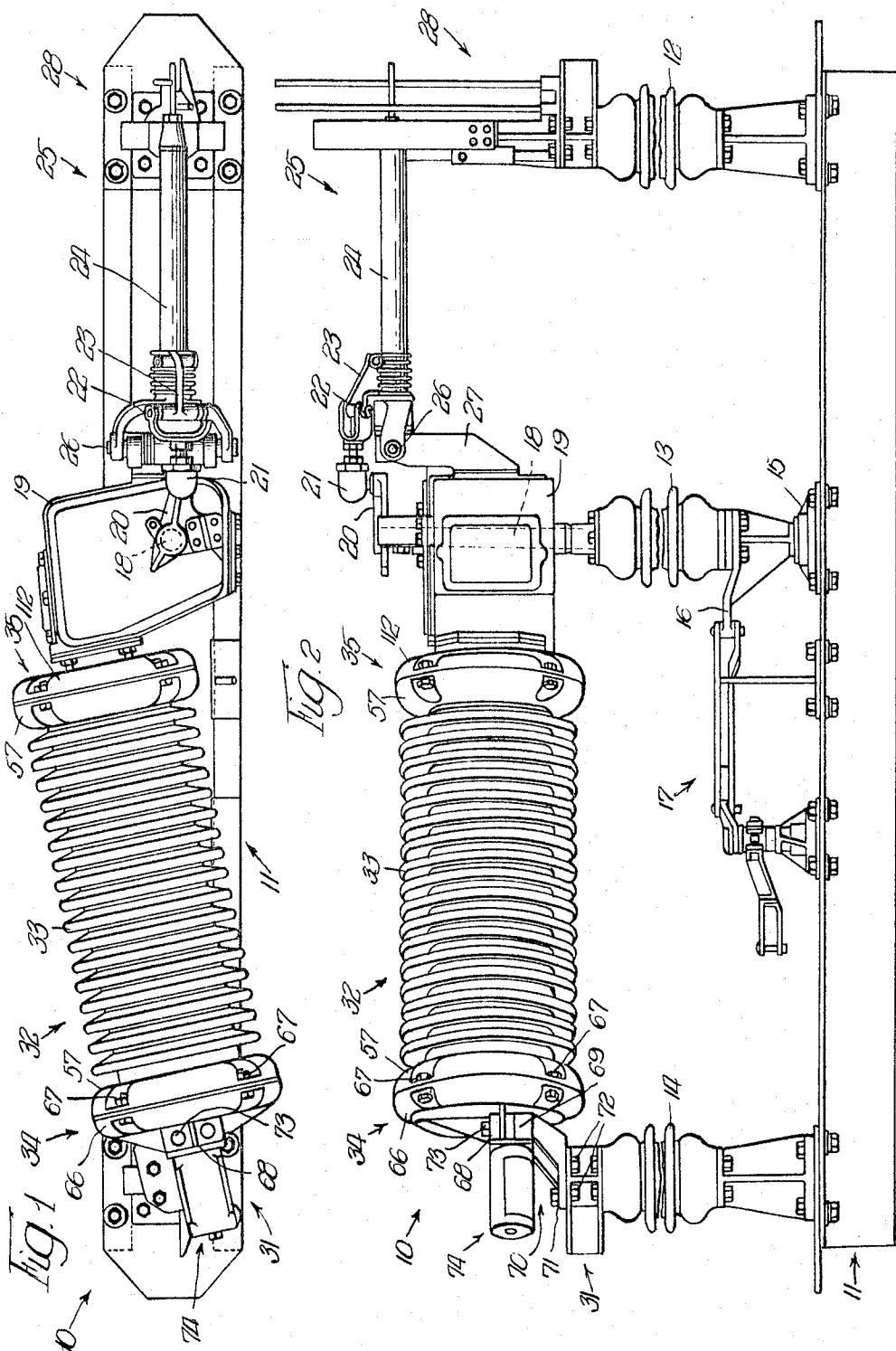
Aug. 23, 1966

S. I. LINDELL
CIRCUIT INTERRUPTER HAVING VACUUM TYPE INTERRUPTER
IN INSULATING GAS FILLED HOUSING

3,268,696

Filed Oct. 30, 1963

6 Sheets-Sheet 1



Aug. 23, 1966

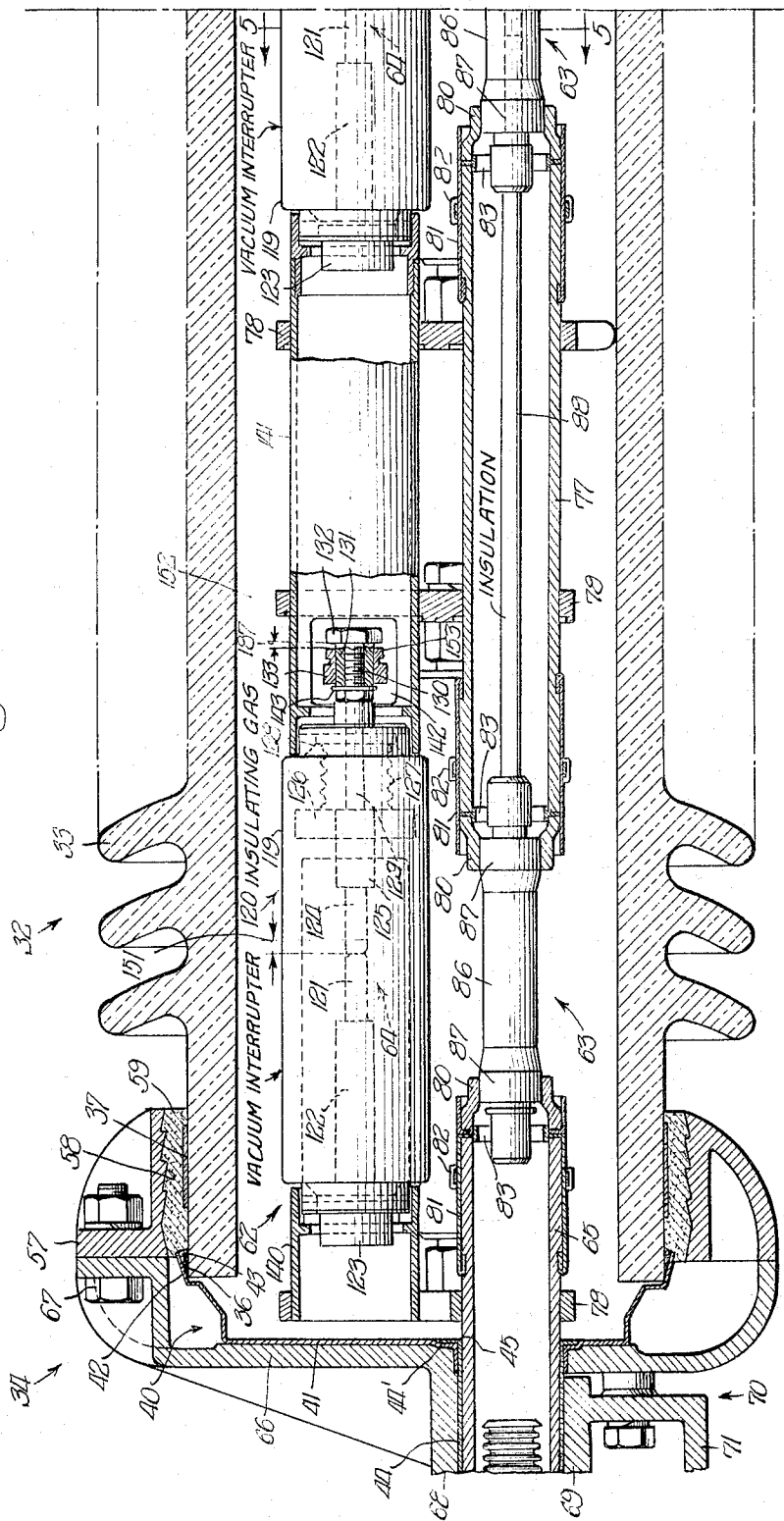
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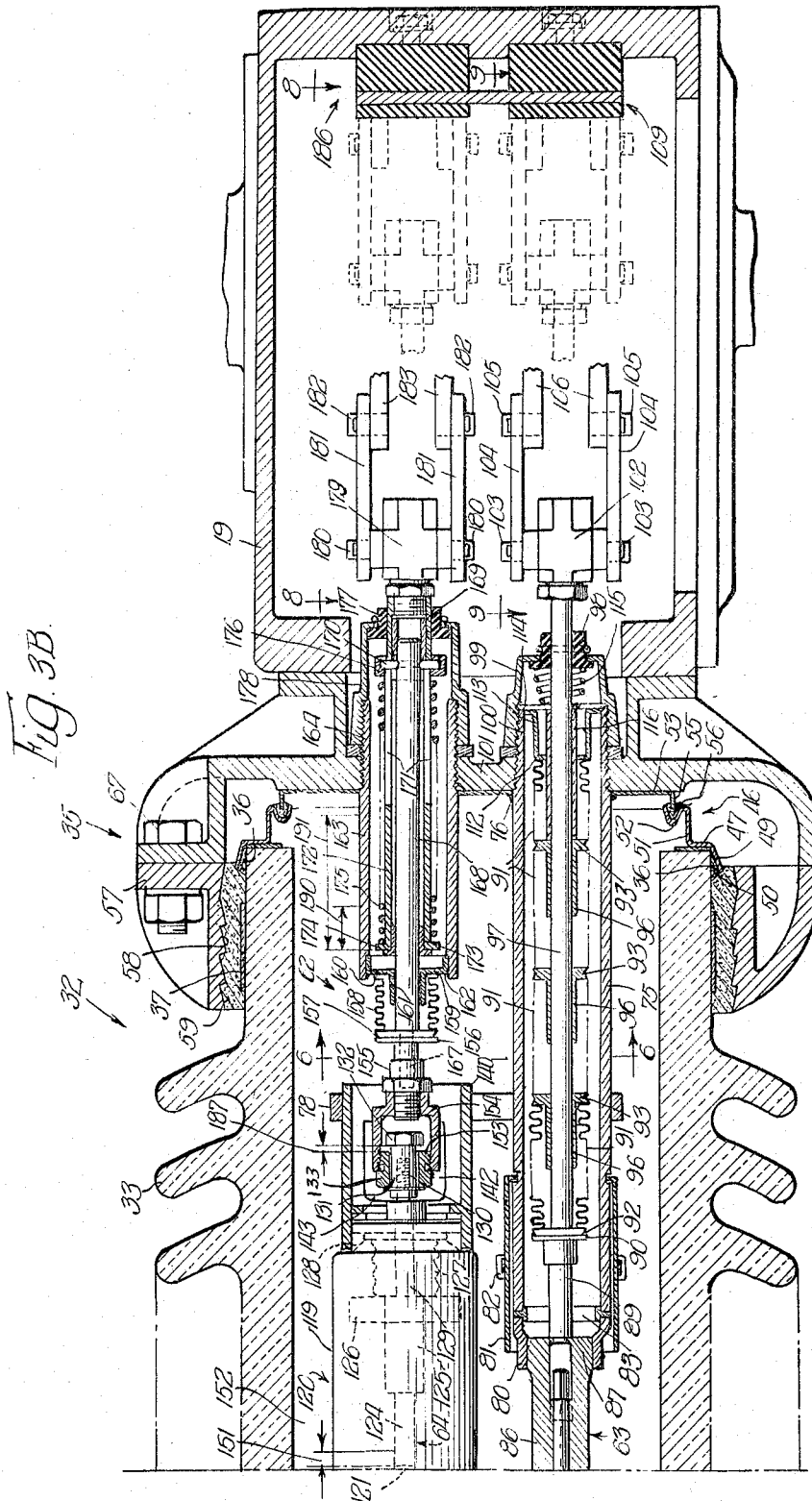
Fig. 3A



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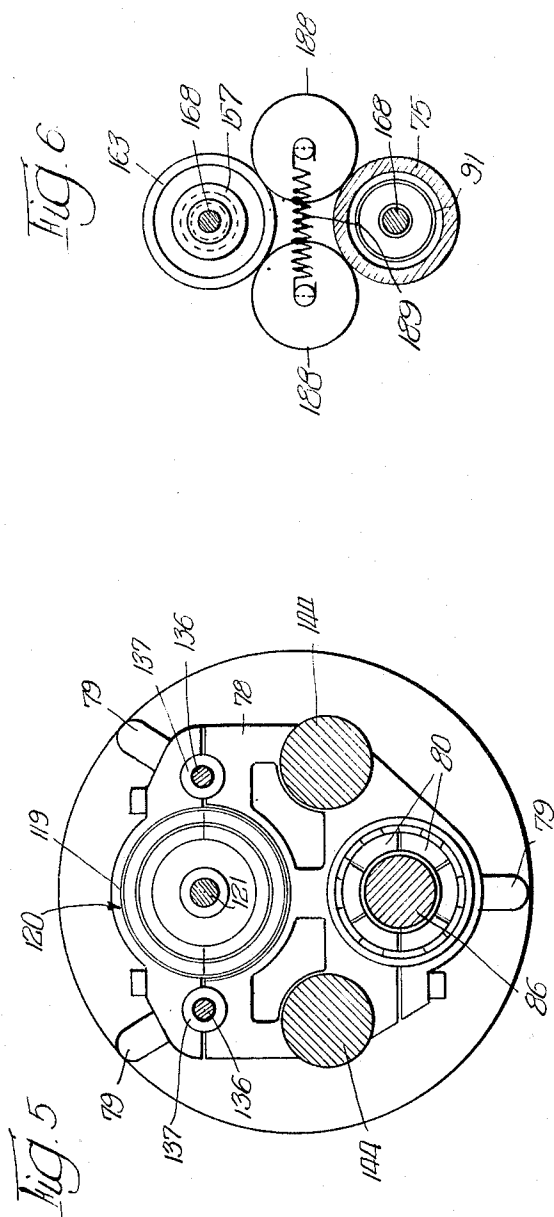
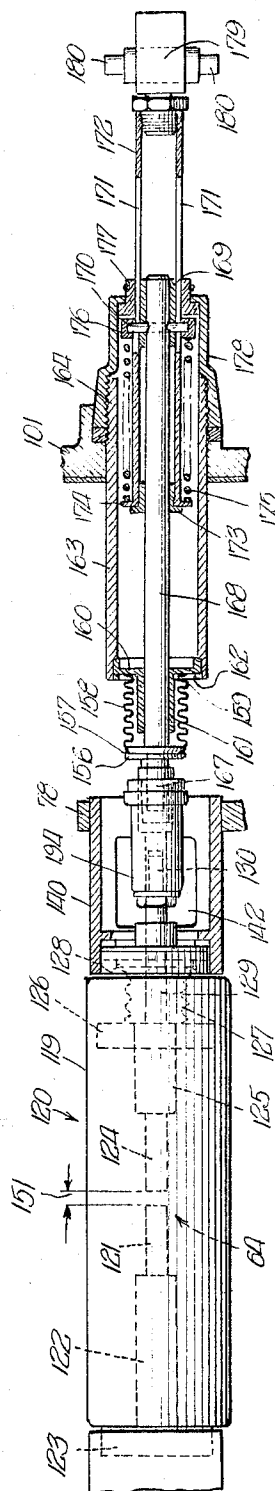
S. I. LINDELL

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Aug. 23, 1966 **S. I. LINDELL** **3,268,696**
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CIRCUIT INTERRUPTER HAVING VACUUM TYPE INTERRUPTER
IN INSULATING GAS FILLED HOUSING

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3,268,696

CIRCUIT INTERRUPTER HAVING VACUUM TYPE INTERRUPTER IN INSULATING GAS FILLED HOUSING

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Filed Oct. 30, 1963, Ser. No. 320,196
23 Claims. (Cl. 200-144)

This invention relates, generally, to circuit makers and breakers and it has particular relation to such devices for use on high voltage alternating current electric power systems operating at voltages of the order of 34.5 kv. and above. It constitutes an improvement over the constructions shown in U.S. Gussow et al. Patent No. 3,030,481, issued April 17, 1962, and in Mikos et al. application Serial No. 111,998, filed May 23, 1961 now Patent No. 3,163,736, issued December 29, 1964.

The construction in U.S. Gussow et al. Patent No. 3,030,481 employs parallel connected main and auxiliary separable contacts in series with a disconnecting switch blade for opening and closing a high voltage alternating current power circuit. The contacts sequentially open the circuit in air with the arc incident thereto being drawn between the auxiliary contacts and extinguished by a blast of gas generated from arc confining insulating means followed by opening of the switch blade. These operations are accomplished in the desired sequence by rotation of a shaft on which main and auxiliary operating arms are rotatably mounted with a spring mechanism biasing them and the main and auxiliary contacts, respectively connected thereto, toward the open position. Suitable latch mechanism is provided to hold the operating arms against the biasing action of the spring mechanism until the shaft has been rotated to a position where the latch for the main operating arm is released. The spring mechanism then rotates the main operating arm to open the main contacts and to trip the latch for the auxiliary arm which then initiates movement of the auxiliary contacts to open position and to interrupt the current flow in the circuit. Subsequent further rotation of the shaft in the same direction swings the disconnecting switch blade to open position, recloses the main and auxiliary separable contacts, and recharge the spring mechanism. The circuit is reclosed by rotating the shaft in the opposite direction to swing the disconnecting switch blade to the closed position.

The main and auxiliary separable contacts of the U.S. Gussow et al. Patent No. 3,030,481 are located in an insulating housing that is vented to the atmosphere. Such a circuit interrupter is subject to the limitations inherent in this type of device. An important consideration involves the voltage across the gap formed by the auxiliary contacts at the time of and immediately after circuit interruption. As the voltage at which the auxiliary contacts are required to interrupt the circuit increases, the ability of this type of device to interrupt the circuit in a satisfactory manner decreases.

In the Mikos et al. application, above referred to, the insulating housing is hermetically sealed and is filled with an arc extinguishing gas, such as SF₆, under pressure above atmospheric pressure. Operators for the main and auxiliary contacts extend out of the sealed housing and bellows interposed therebetween permit the necessary movement of the operators while maintaining the fluid tight integrity of the housing. Since the internal gas pressure exceeds atmospheric pressure, there is a net force acting on the bellows in a direction to oppose the closing of the main and auxiliary contacts. Thus the closing forces applied to the operators are required to overcome the opposing forces at both bellows and, for the auxiliary butt contacts, to provide force sufficient to cause adequate butt

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contact pressure therebetween to facilitate carrying of momentary relatively high current flow, while the main contacts are being separated a sufficient distance before tripping the latch for the auxiliary contact arm.

Among the objects of this invention are: To provide for sealing the insulating housing in which the main separable contacts are located, to fill the sealed housing with an insulating gas, and to employ a vacuum type interrupter in the sealed and gas filled housing for effecting the circuit interruption; to reduce the likelihood that the vacuum type interrupter will flash over the outer surface of its vacuum housing when it is subjected to a steep wave front transient recovery voltage with its contacts in their open position; to match the insulation between the terminals of the vacuum type interrupter over the surface of its vacuum housing with the insulation between its contacts when they are separated; to immerse the vacuum type interrupter in a gas capable of providing a high degree of insulation over the surface of its vacuum housing and a dielectric strength substantially greater than air at atmospheric pressure; to provide a plurality of series connected vacuum type interrupters in tandem in the gaseous insulating medium actuated by insulating members of relatively short length; to shunt the contacts of the vacuum type interrupter with high capacity main or load current carrying contacts; to open sequentially the main or load current carrying contacts and the auxiliary or vacuum type contacts for transferring the current flow to the latter where it is interrupted on separation thereof; to open the auxiliary or vacuum type contacts by moving one of them away from the other through the usual small distance by an operating member that moves through a substantially greater distance; to interpose a spring between the movable vacuum type contact and the operating member for operating the former through its relatively short stroke without requiring critical adjustment of the operating member; to place the insulating gas under pressure in the housing and to utilize this pressure for biasing the contacts of the vacuum type interrupter to the closed position; to operate the movable contact of the vacuum type interrupter by a member extending out of the sealed and gas filled insulating housing and subject to the gas pressure within the housing and to atmospheric pressure outside this housing; to employ a bellows unit associated with the movable contact of the vacuum type interrupter and another bellows unit associated with the operator extending out of the housing in which the gas pressure acts in opposite directions on the bellows units in combination with an external spring that moves the operator with a straight line motion in opposition to the force acting on the bellows unit of the vacuum interrupter in a direction tending to hold the movable contact in closed position; and to operate a plurality of vacuum type interrupters in tandem by an operating member extending out of the sealed and gas filled insulating housing and to provide a lost motion connection to the movable contact of each interrupter to permit the gas pressure to bias the contacts closed to act individually on each movable vacuum type contact.

In the drawings:

FIG. 1 is a top plan view of switch means embodying the present invention, the switch means being shown in the closed position.

FIG. 2 is a view, in side elevation, of the switch means shown in FIG. 1.

FIGS. 3A and 3B, taken together with the views being placed in end to end relation, show at an enlarged scale a vertical cross sectional view of the current interrupter which forms a part of the switch means shown in FIGS. 1 and 2.

FIGS. 4A and 4B, taken together in end to end rela-

tion, constitute a top plan view of the series connected contact structure within the insulating housing of the current interrupter shown in FIGS. 3A and 3B, certain parts being broken away in order to show details of construction.

FIG. 5 is a vertical sectional view taken generally along the line 5—5 of FIG. 3A.

FIG. 6 is a vertical sectional view taken generally along the line 6—6 of FIG. 3B.

FIG. 7 shows the contacts of the vacuum type interrupter in the open position with a modified form of connection between the operating mechanism and the movable vacuum type contact.

FIG. 8 is a horizontal sectional view taken generally along the line 8—8 of FIG. 3B.

FIG. 9 is a horizontal sectional view taken generally along the line 9—9 of FIG. 3B.

Referring now particularly to FIGS. 1 and 2 of the drawings, it will be observed that the reference character 10 designates, generally, switch means in which the present invention is embodied. The switch means 10 includes a base, indicated generally at 11, that may be formed of a pair of rolled steel channels suitably secured together. Mounted on the base 11 are a first insulator 12, a second insulator 13, which is rotatable, and a third insulator 14. The second insulator 13 is rotatably mounted on a bearing 15 that is carried by the base 11 and it has an arm 16 extending therefrom for connection to a suitable operating linkage that is indicated, generally at 17. It will be understood that, for three phase operation, three of the switch means 10 are mounted on a suitable switching structure in proper spaced relation, depending upon the voltage of the circuit, and that suitable operating means, connected to the operating linkage 17, is provided for effecting simultaneous rotation of the second insulator 13 of each such switch means 10 for either opening or closing the circuit as may be required. Such an operating mechanism is illustrated and described in U.S. Gussow et al. Patent No. 3,030,481, above referred to.

Extending upwardly from and rotatable with the second insulator 13 is a shaft 18. The shaft 18 extends through and is rotatably mounted on a mechanism housing 19 the details of construction of which are set forth in the patent above referred to together with the operating mechanism therein which is controlled by the shaft 18. Certain modified details of construction of the operating mechanism will be set forth hereinafter. For present purposes it is pointed out that the shaft 18 extends through the mechanism housing 19 and carries at its upper end a switch crank 20 which is rotatable therewith. The switch crank 20 is pivotally connected to a link 21 that is pivoted at 22 to an arm 23 which extends from a switch blade 24 that forms a part of a disconnecting switch, indicated generally at 25. The switch blade 24 is pivoted at 26 on a bracket 27 which is carried by one wall of the mechanism housing 19. At its distal end the switch blade 24 is arranged to move into and out of high pressure contact engagement with a line contact member, shown generally at 28, which is carried by the first insulator 12. It will be understood that, on rotation of the second insulator 13 by the operating linkage 17, a corresponding rotation of the switch crank 20 is effected for swinging the switch blade 24 out of or into high pressure contact engagement with the line contact member 28, depending upon the direction of rotation. The details of construction of the disconnecting switch 25 are conventional and may be as disclosed in U.S. Gussow Patent No. 2,818,474, issued December 31, 1957.

It is desirable that the switch blade 24 be opened only after the circuit has been opened previously by some other means. The reason for this is to prevent the drawing of an arc between the distal end of the switch blade 24 and the line contact member 28 when the circuit is interrupted under load which might result in damage to these parts or the creation of a fault by arcing over to an

adjacent phase or to ground. For this purpose there is mounted between the mechanism housing 19 and a line terminal 31, which is carried by the third insulator 14, a current interrupter that is indicated generally at 32.

FIGS. 3A and 3B illustrate the details of construction of the current interrupter 32. Here it will be observed that the current interrupter 32 is provided with an insulating housing 33 that preferably is a one piece hollow porcelain housing having a cylindrical interior and external corrugations to increase its flashover value between the ends. At its ends the insulating housing 33 is provided with terminals that are indicated, generally, at 34 and 35. Provision is made as described in Mikos et al. application Serial No. 111,998, filed May 23, 1961, for securing the terminals 34 and 35 to the ends of the insulating housing 33. As there disclosed the end portions of the insulating housing 33 have a platinum band 36 on each and spaced therefrom is a sand band 37. At the left end of the insulating housing 33, FIG. 3A, there is provided a pan-shaped diaphragm 40 having a flat bottom 41 and an outflared rim 42 which is secured by solder 43 to the juxtaposed platinum band 36. Below the central portion of the flat bottom 41 of the diaphragm 40 there is a tubular extension 44 having a radial flange 44' that is brazed at 45 to the overlying portion of the flat bottom 41. At the right end of the insulating housing 33, FIG. 3B, there is positioned a pan-shaped diaphragm 46 having an annular portion 47 which overlies the adjacent end portion of the insulating housing 33. The diaphragm 46 has an outflared rim 49 that is secured by solder 50 to the juxtaposed platinum band 36. The diaphragm 46 also includes a cylindrical portion 51 that extends endwise from the insulating housing 33 and it has an annular outwardly opening grooved end portion 52 for connection to a backup plate 53. The backup plate 53 has an annular rim 55 along its periphery for interfitting with the annular grooved end portion 52 of the diaphragm 46 and the two are secured together by solder 56. This construction facilitates the assembly of the separable contact structure in the insulating housing 33 as will be described presently.

In order to mount the insulating housing 33, adapter rings 57 are mounted on its ends. They are provided with corrugated inner surfaces 58. A filling of Portland cement 59 overlies the corrugated inner surfaces 58 and the sand bands 37 to provide the necessary rigid mechanical connection.

As pointed out hereinbefore the insulating housing 33 contains a separable contact structure which is employed for interrupting the flow of current in the circuit in which the switch means 10 is connected and drawing and extinguishing the arc or arcs that may be incident thereto. The rigid separable contact structure is indicated generally at 62 and it comprises, for the construction shown in FIGS. 3A-3B, series connected sets of separable main contacts, indicated generally at 63—63, and series connected sets 64—64 of separable auxiliary or vacuum type contacts with the sets of main and auxiliary contacts being connected in parallel and the arrangement being such that the sets of main contacts 63—63 are opened first to transfer the entire flow of current to the series connected auxiliary or vacuum type contacts 64—64. Thereafter the series connected auxiliary or vacuum type contacts 64—64 are opened to draw and extinguish arcs in a manner to be described.

As shown in FIG. 3A a heavy gage copper tube 65 forms a part of the main separable main contacts 63 at the left end of the insulating housing 33. The copper tube 65 extends through a terminal end adapter 66 which overlies the flat bottom 41 of the diaphragm 40. It is secured by bolts 67 to a radially outwardly extending flange on the adjacent adapter ring 57. As described in more detail in application Serial No. 111,998, filed May 23, 1961, semicircular sections 68 and 69 are associated with the terminal end adapter 66 for the purpose of

mounting it on the terminal end support 70 which has a pad portion 71 to facilitate mounting on the line terminal 31 to which a line conductor can be connected. Bolts 72 serve to secure the pad portion 71 to the line terminal 31 and bolts 73 interconnect the semicircular sections 68 and 69 and clamp them to the heavy gage copper tube 65.

Since the heavy gage copper tube 65 opens into the interior of the insulating housing 33, advantage is taken of this arrangement to provide an exterior indication as to whether the desired predetermined pressure of insulating gas is being maintained within the insulating housing 33. For this purpose an indicator, shown generally at 74 in FIGS. 1 and 2, is employed. The details of construction of the indicator 74 are set forth in U.S. Goldbach et al. Patent No. 3,077,527, issued February 12, 1963.

At the right end of the insulating housing 33, FIG. 3B, there is positioned a heavy gage copper tube 75 in alignment with the copper tube 65 at the left end. It extends through the backup plate 53 and is brazed thereto as indicated at 76. Intermediate the copper tubes 65 and 75 and in alignment therewith is an intermediate heavy gage copper tube 77, FIG. 3A. It will be understood that the heavy gage copper tubes 65, 75 and 77, which form parts of the separable main contacts 86—86, are employed for conducting the normal load current through the current interrupter 32 under normal operating conditions. It is for this reason that these parts are formed of relatively good conducting material having substantial cross section.

The intermediate heavy gage copper tube 77 is mounted intermediate its ends on support plates 78—78. As shown in FIG. 5 these support plates are spaced from the inner surface of the insulating housing 33 by bumpers indicated at 79. Attention is directed to the fact that there are four support plates 78. They are arranged in pairs with a rigid supporting structure therebetween that will be described presently. The facing ends of the copper tubes 65, 75 and 77 are longitudinally slotted to provide contact fingers 80 which are urged inwardly by leaf springs 81 that are held in position by retainer rings 82. A spreader ring 83 extending underneath each set of contact fingers 80 serves to limit the inward movement thereof.

It will be observed that the ends of the intermediate copper tube 77 are spaced from the inner ends of the copper tubes 65 and 75. This arrangement provides the necessary gap in the insulating gaseous atmosphere in the insulating housing 33. In the construction shown in FIGS. 3A and 3B two gaps in series are provided. For bridging these gaps cylindrical movable contacts 86—86 are employed. They have large diameter ends 87—87 for the purpose of making good contact engagement with the inner surfaces of the juxtaposed contact fingers 80. In FIGS. 3A and 3B the cylindrical movable contacts 86—86 are shown in the circuit closed positions and it will be understood that they are moved endwise conjointly when the circuit is to be opened. For this purpose the cylindrical movable contacts 86—86 are interconnected by an insulating operating rod 88 which extends through the intermediate copper tube 77 and is rigidly secured at its ends to the movable contacts 86—86.

At the right end of the movable contact 86 shown in FIG. 3B, it is connected to an operating rod insert 89 in a suitable manner. The other end is rigidly secured to an end guide washer 90 that is located at one end of a number of bellows units 91 arranged in tandem. The left end of the left bellows unit 91 is soldered as indicated at 92 to the end guide washer 90. Intermediate guide washers 93 are located between the juxtaposed ends of the bellows units 91 and these ends are soldered thereto. Intermediate tubular spacers 96 are suitably secured to the inner portions of the intermediate guide washers 93 for the purpose of limiting the compression of the respective bellows unit 91. In addition the tubular spacers 96, as outlined in Mikos et al. application Serial No. 111,998, filed May 23, 1961, serve to guide the bellows units 91

in their movement between the circuit closed and the circuit open position.

Telescoped with the bellows units 91 and the intermediate tubular spacers 96 is a rod-like operator 97 which is connected at its left end, as seen in FIG. 3B, to the operating rod insert 89 to effect conjoint movement of the movable main contacts 86—86 from and to the circuit closed position. At its right end the rod-like operator 97 extends through and is guided by an insulating guide bushing 98 that is mounted on a clamp nut 99. The clamp nut 99 is threaded on the threaded end 100 of the heavy gage copper tube 75 that projects through a mechanism end adapter 101 which is secured by the bolts 67 to the adapter ring 57. The projecting end of the rod-like operator 97 is connected to a cross head 102 having oppositely extending trunnions 103—103 to which links 104—104 are pivotally attached at one end. The other ends of the links 104—104 are pivotally mounted on trunnions 105—105 that extend from arms 106—106 that are formed integrally with a main operating arm 107, FIG. 9, that is rotatably mounted on the shaft 18. A spring 108 is arranged to bias the main operating arm 107 toward the clockwise direction as viewed in FIG. 9 for the purpose of moving the main contacts 86—86 to the open position. A suitable latch mechanism, as described in the U.S. Gussow et al. Patent No. 3,030,481 is provided for controlling the release of the main operating arm 107 on predetermined rotation of the shaft 18. At the end of the opening movement of the main operating arm 107, the arms 106—106 engage a resilient bumper, shown generally at 109, and mounted on a wall of the mechanism housing 19.

In order to seal the connection between the rod-like operator 97 and the interior of the insulating housing 33 while permitting movement of the rod-like operator 97, the right end of the right bellows unit 91 is soldered at 112 to a bellows head 113 that, in turn, is soldered at 114 to the projecting threaded end 100 of the heavy gage copper tube 75. A spiral bumper spring 115 is interposed between the flanged inner end of the insulating guide bushing 98 and the right end of a tubular end spacer 116 which is telescoped over the rod-like operator 97 with its left end bearing against the adjacent intermediate guide washer 93.

It will be recalled that the separable auxiliary contacts 64 are provided for interrupting the current flow through the current interrupter 32 after opening of the main contacts 63. In accordance with this invention the auxiliary contacts 64, of which there are two sets in series in the embodiment shown in FIGS. 3A—3B, are located in a vacuum housing 119, preferably formed of glass, of a vacuum type circuit interrupter, shown generally at 120, and of conventional design. Within each vacuum housing 119 there is provided a stationary contact 121 that extends from a stationary terminal 122 having an external terminal 123 at one end of the housing 119 to permit connection thereto. Cooperating with the stationary contact 121 is a movable contact 124 that is carried by a movable terminal 125 that has associated therewith a terminal head 126. It will be understood that the stationary contact 121 and the movable contact 124 comprise the set of separable auxiliary contacts 64. In order to maintain the vacuum within the vacuum housing 119 while permitting movement of the movable terminal 125, a bellows unit 127 is connected between the terminal head 126 and the end 128 of the vacuum housing 119. Because of the vacuum within the vacuum housing 119 the ambient pressure acts in a direction to bias the movable contact 124 into engagement with the stationary contact 121.

For operating the movable contact 124 a movable terminal extension rod 129 projects from the movable terminal 125 through the end 128 of the vacuum housing 119 where its threaded end 130 is secured to a sleeve 131 having an integral head 132 that may be hexagonal in

configuration. The sleeve 131 has limited sliding movement in a central portion 133 of a bridge 134 that is provided with oppositely extending arms 135—135, FIGS. 4A—4B, that are interconnected by insulating rods 136—136 which are guided for sliding movement by bushings 137—137 in the intermediate support plates 78. The arrangement is illustrated in FIG. 5. It provides for conjoint opening movement of the movable contacts 124 of the tandem arranged vacuum type circuit interrupters 120—120.

Provision is made for connecting the vacuum type circuit interrupters 120—120 in series and in parallel relation to the separable main contacts 63—63. They are arranged as a part of the rigid separable contact structure 62. For this purpose end connector sleeves 140—140 are provided, one at the left end of the left vacuum type circuit interrupter 120 and the other at the right end of the right vacuum type circuit interrupter 120. They are resiliently mounted in and secured to the associated support plate 78. An intermediate connector sleeve 141 mounted on and secured to the intermediate support plates 78 serves to interconnect the adjacent ends of the vacuum type circuit interrupters 120 as well as as providing mechanical support therefor. Appropriate openings 142—142 are provided in opposite sides of the right end connector sleeve 140 and the intermediate connector sleeve 141 to permit extension of the arms 135—135 that form part of the bridges 134 which are interconnected by the insulating rods 136—136 for effecting conjoint movement of the movable contacts 124—124. Flexible shunts 143—143 serve to interconnect the respective movable contacts 124—124 and the associated support plates 78—78 one of which is mounted on and connected to the intermediate heavy gage copper tube 77 while the other is mounted on and connected to the heavy gage copper tube 75 at the right end of the current interrupter 32.

The rigid separable contact structure 62 also includes porcelain insulator rods 144—144 having support posts 145—145 at their ends for connection respectively to the left set of support plates 78—78 and to the right set of support plates 78—78. One of the porcelain insulator rods 144 of each set is provided with a resistance coating material 146 for the purpose of maintaining the proper voltage division through the current interrupter 32 when the separable main contacts 63—63 and the separable auxiliary contacts 64—64 are open. Connection to the resistance coating material 146 is provided by contact springs 147—147 which are interposed between the associated support plates 78—78 and the adjacent ends of the resistance coating material 146. An insulating glass tube 148 is telescoped over the resistance coating material 146 to protect it.

When a vacuum type circuit interrupter 120 is mounted in air at atmospheric pressure, it is often the case under certain circuit conditions that the impulse withstand value over the surface of the vacuum housing 119 is less than the impulse withstand value between the contacts 121 and 124 when they are separated as indicated at 151 in FIGS. 3A—3B and in FIG. 7 where the actual separation is shown. Accordingly, when the vacuum type circuit interrupter 120 is subjected to a steep wave front transient recovery voltage such as that incident to switching surges under conditions producing current chopping, it may flash over the surface of the vacuum housing 119. This tendency is aggravated by non-simultaneous contact separation and build up of dielectric strength in the gaps of series connected interrupters with attendant unequal voltage distribution. Thus one unit may flash over at a time. With a view to overcoming this disadvantage the insulating housing 33, which is completely sealed, is filled with an insulating gas, indicated at 152, at a pressure providing greater dielectric strength than that of air at atmospheric pressure. The pressure of the gas 152 may be above atmospheric pressure, preferably two atmos-

pheres by gage. The insulating gas 152 can be any gas that is effective to increase the insulation over the surface of the vacuum housing 119 to such an extent that it matches the voltage withstandability of the gap 151 between the contacts 121 and 124 in the open position during and following arc extinction and has a dielectric strength substantially greater than the dielectric strength of air at atmospheric pressure. For example, for certain duties compressed air can be used at two atmospheres pressure by gage for the gas 152. In addition nitrogen, SF₆ and other like insulating gases at suitable pressures can be employed for the gas 152 provided they remain in the gaseous state at any low temperature likely to be encountered. SF₆ or like insulating gases of inherently greater dielectric strength than air can be employed at atmospheric pressure in the insulating housing 33 to simplify the sealing thereof.

In order to effect conjoint movement of the movable contacts 124—124, the bridge 134 associated with the right end 128 of the right vacuum type circuit interrupter 120 is provided with a threaded boss 153 to which a coupling nut 154 is attached at one end while its other end is threaded on one end of a fitting 155. The other end of the fitting 155 includes an end guide washer 156 that is soldered at 157 to the adjacent end of a bellows unit 158. The other end of the bellows unit 158 is soldered at 159 to a radial flange 160 which extends from a guide sleeve 161 and is soldered at 162 to the left end of a heavy gage copper tube 163 the right end of which is threaded at 164 and extends through the mechanism end adapter 101. It will be apparent that this arrangement provides for atmospheric pressure to be applied to the outer side of the bellows unit 158 and end guide washer 156 with the result that atmospheric pressure acts in a direction to bias the fitting 155 and parts attached thereto inwardly and against the pressure exerted on the inside by the insulating gas 152. The pressure of the insulating gas 152 and the effective areas of the bellows 127 and 158 can be chosen so that the pressure exerted thereby balances the pressure exerted by the atmosphere or the selection can be made to deliver a force of predetermined magnitude to the fittings 155 in one direction or the other.

A threaded end 167, FIG. 3B, of a connecting rod 168 is secured to the fitting 155 here shown. The connecting rod 168 extends outwardly through the heavy gage copper tube 163 and its right end is provided with a guide sleeve 169 through which a cross pin 170 extends. The ends of the cross pin 170 project through longitudinally extending slots 171—171 in a tensioning tube 172 that is telescoped over the connecting rod 168. A guide flange 173 at the left end of the tensioning tube 172 serves to position the connecting rod 168 centrally with a minimum of friction. At its left end the tensioning tube 172 has a radially outwardly extending flange 174 against which one end of a coil compression spring 175 reacts. The other end of the coil compression spring 175 bears against a cup washer 176 that reacts against the ends of the cross pin 170. This construction provides a lost motion connection between the connecting rod 168 which is connected directly to the fitting 155 and the tensioning tube 172. Such an arrangement is required since the movement of the movable contacts 124 is through a relatively short distance as indicated at 151 while provision is made for moving the tensioning tube 172 through a relatively greater distance.

The right end of the tensioning tube 172 extends through and is guided by an insulating guide bushing 177 that is carried by a clamp nut 178 which is threaded onto the threaded end 164 of the heavy gage copper tube 163. The projecting end of the tensioning tube 172 is mechanically connected to a cross head 179 which has oppositely extending trunnions 180—180 to which links 181—181 are pivoted. The other ends of the links 181—181 are pivoted to trunnions 182—182 that extend from arms

183—183 at the distal end of an auxiliary operating arm 184, FIG. 8, that is rotatably mounted on the shaft 18. The auxiliary operating arm 184 is biased in a clockwise direction by a spring 185 and is held against movement by a latch as described in detail in U.S. Gussow et al. Patent No. 3,030,481. A resilient bumper shown generally at 186, FIG. 3B, and mounted on the mechanism housing 19, serves to limit the opening movement of the auxiliary operating arm 184 when the arms 183—183 engage the same.

It will be recalled that the sleeve 131, which is mechanically directly connected to the respective movable contact 124 in each of the vacuum type circuit interrupters 120 is slidable within the central portion 133 of the associated bridge 134. In the closed position of the movable contacts 124—124 the head 132 integral with the associated sleeve 131 is spaced a slight distance indicated at 187 from the adjacent end of the threaded boss 153 that forms a part of the central portion 133 of the bridge 134. This lost motion distance 187 permits the movable contacts 124 to seat individually against the respective stationary contacts 121 under the biasing action of the ambient pressure within the sealed insulating housing 33. The arrangement is such that, when the auxiliary operating arm 184 has been moved to the switch closed position the ends of the cross pin 170 bear against the right ends of the slots 171—171 in the tensioning tube 172 with the result that the connecting rod 168 is moved inwardly or to the left as viewed in FIG. 3B. This is accompanied by movement of the bridges 134—134 which are interconnected by the insulating rods 136—136. The arrangement is such that this movement is in excess by the lost motion distance 187 of that required to permit the ambient pressure within the sealed insulating housing 33 to move the movable contacts 124—124 into engagement with the respective stationary contacts 121—121. When they are to be opened, it is necessary that the lost motion distance 187 in each case be taken up by movement of the respective bridge 134 before opening movement of the contacts 124 is effected.

It will be understood that a prestressed compression spring can be interposed between each bridge 134 and the respective movable contact 124 to provide additional predetermined pressure between the separable contacts 64 of the individual vacuum interrupters 120—120 to increase their capability for carrying high momentary overload currents.

In the event that there is a likelihood that the insulating gas 152 in the housing 33 will deteriorate, provision can be made for absorbing impurities. For this purpose, as seen in FIG. 6, housings 188—188 are provided between the heavy gage copper tubes 75 and 163 for receiving a suitable chemical such as activated alumina. Springs, one of which is shown at 189, serve to hold the housings 188—188 in position.

In operation, when it is desired to open the circuit by operating the current interrupter 32, the shaft 18 is rotated in a manner described in U.S. Gussow et al. Patent No. 3,030,481. A latch is tripped which releases the main operating arm 107, FIG. 9, to rotate under the influence of the spring 108. This moves the rod-like operator 97 to the right and opens the separable main contacts 63—63. The entire current flow is then transferred to the separable auxiliary contacts 64—64 in the vacuum type circuit interrupters 120—120. Continued rotation of the main operating arm 107 trips a latch which releases the auxiliary operating arm 184, FIG. 8, and it begins to rotate under the biasing action of the spring 185. Rotation of the auxiliary operating arm 184 causes endwise movement of the tensioning tube 172. Initially the coil compression spring 175 is further compressed as the result of the endwise movement of the tensioning tube 172. Shortly thereafter the lost motion distance 187 is taken up and then the force transmitted through the additionally compressed spring 175 reacts directly against the movable

contacts 124—124 in a direction opposite to the direction in which the ambient pressure acts to bias them to the closed position. When the tensioning tube 172 has moved through a further distance as indicated at 190 in FIG. 3B, the force now transmitted through the spring 175 is sufficient to initiate opening movement of the contacts 124—124 and they begin to part to establish the gap distance 151. As the force exerted by the spring 175 increases due to further movement in a clockwise direction of the auxiliary operating arm 184, FIG. 8, the contacts 124—124 are moved to the full open position at an accelerated rate to provide the gap 151. The continued movement of the auxiliary operating arm 184 in the clockwise direction moves the tensioning tube 172 to the end of the stroke indicated at 191 in FIG. 3B. The position of the parts in the open position is shown in FIG. 7. In the full open position and at the end of the opening stroke the coil compression spring 175 acts as a shock absorber and the continued application of force to the auxiliary operating arm 184 by the spring 185 is sufficient to prevent the movable contacts 124—124 bouncing back to the closed position.

Although the opening movement of the contacts 124—124 is effected by the translatory motion of the tensioning tube 172 and the cross head 179, the actual movement of the contacts is effected initially at a relatively low speed and later at a rapidly increasing higher speed. This is effected by interrelation between the resultant pressure of the gas 152 acting on the bellows 127 and 158 in relation to atmospheric pressure acting on the bellows 158 together with the action and increasing force of the compression spring 175 associated with the lost motion that is effective through the use of the cross pin 170 and the slots 171.

As described in the U.S. Gussow et al. Patent No. 3,030,481 the continued rotation of the shaft 18 causes the switch blade 24 to be swung to the open position. In addition the main operating arm 107 and the auxiliary operating arm 184 are rotated in counterclockwise directions to reclose the separable main contacts 63—63 and the separable auxiliary contacts 64—64. During the closing operation the coil compression spring 175 aids in overcoming the opposing force of the bellows unit 158. In the full open position of the switch blade 24 the separable main contacts 63—63 and the separable auxiliary contacts 64—64 are closed. On reverse rotation of the shaft 18, the switch blade 24 is swung to the closed position shown in FIGS. 1 and 2 for completing the circuit.

FIG. 7 shows a single vacuum type circuit interrupter 120 that can be employed in an insulating housing such as insulating housing 33 that is provided with only a single set of separable main contacts 63. In such an arrangement it is unnecessary to provide the lost motion distance at 187. For this construction a coupling fitting 194 is employed which makes a direct connection between the movable terminal extension rod 129 and the connecting rod 168.

By introducing the lost motion at the exterior of the housing 33 and by suitable choice of effective areas of the bellows units 127 and 158 without lost motion within the housing 33, the bellows unit 158 can be made to affect part of the force on the auxiliary contacts 64 derived from the internal pressure of the gas 152. Thus the pressure between the auxiliary contacts 64 can be made independent of the pressure of the gas 152 if so desired.

What is claimed as new is:

1. A circuit interrupter for use in air at atmospheric pressure comprising:

(a) a tubular insulating member having terminals at its ends and members closing its ends to form a gas-tight non-vented tubular insulating housing for permanently containing and confining a quantity of insulating gas at a pressure substantially above atmospheric pressure and independent of variations in pressure of the ambient air,

- (b) a vacuum type interrupter unit in said housing having separable current interrupting contacts in a vacuum housing connected respectively to said terminals,
- (c) an insulating gas in said tubular gas tight housing and immersing said vacuum housing characterized by having a pressure substantially above atmospheric pressure and a dielectric strength at such pressure substantially greater than the dielectric strength of air at atmospheric pressure and providing insulation over the surface of said vacuum housing matching the voltage withstandability of the gap between said contacts while they are being separated for arc extinction and in their open position following arc extinction and providing a force biasing said contacts toward their closed position, and
- (d) means for overcoming the biasing action of said insulating gas in said insulating housing for opening said current interrupting contacts.
2. The invention, as set forth in claim 1, wherein the gas inherently has a greater insulating value than air.
3. The invention, as set forth in claim 1, wherein the gas is SF₆.
4. The invention, as set forth in claim 3, wherein the gas has a pressure above two atmospheres gage.
5. The invention, as set forth in claim 1, wherein the gas is air at a pressure of at least two atmospheres gage.
6. The invention, as set forth in claim 1, wherein:
- (a) a disconnecting switch is connected in series circuit relation with the current interrupting contacts, and
- (b) the means for opening said current interrupting contacts includes means for opening said disconnecting switch after said current interrupting contacts have been opened.
7. The invention, as set forth in claim 6, wherein the contact and switch operating means includes means for first closing the current interrupting contacts followed by closing the disconnecting switch.
8. The invention, as set forth in claim 1, wherein:
- (a) load carrying separable contacts are located in the gas filled housing and connected in parallel with the current interrupting contacts, and
- (b) the means for opening the current interrupting contacts includes means for opening said load carrying contacts before said current interrupting contacts are opened.
9. The invention, as set forth in claim 8, wherein the gas is SF₆.
10. The invention, as set forth in claim 8, wherein:
- (a) a disconnecting switch is connected in series circuit relation with the parallel connected current interrupting and load carrying contacts, and
- (b) the means for sequentially opening said contacts includes means for opening said disconnectings which after said contacts have been opened.
11. The invention, as set forth in claim 10, wherein the contact and switch operating means includes means for first closing the contacts followed by closing the disconnecting switch.
12. A circuit interrupter comprising:
- (a) a tubular gas tight insulating housing having terminals at its ends,
- (b) a vacuum type interrupter unit in said housing having separable current interrupting contacts in a vacuum housing connected respectively to said terminals,
- (c) an insulating gas in said tubular gas tight housing and immersing said vacuum housing characterized by providing insulation over the surface of said vacuum housing matching the voltage withstandability of the gap between said contacts while they are being separated for arc extinction and in their open position following arc extinction, dielectric strength substantially greater than the dielectric strength of air

- at atmospheric pressure, and a force biasing said contacts toward their closed position,
- (d) a spring biasing said contacts toward their open position with a force less than the force due to said gas pressure acting to hold said contacts in their closed position, and
- (e) means for opening said contacts acting through said spring to increase its biasing force to overcome the biasing force exerted on said contacts by said insulating gas.
13. A circuit interrupter comprising:
- (a) a tubular gas tight insulating housing having terminals at its ends,
- (b) a vacuum type interrupter in said housing having separable current interrupter contacts in a vacuum housing connected respectively to said terminals,
- (c) an insulating gas in said tubular gas tight housing immersing said vacuum housing and characterized by providing dielectric strength substantially greater than the dielectric strength of air at atmospheric pressure and biasing said current interrupting contacts toward their closed position,
- (d) a spring for biasing said current interrupting contacts toward their open position, and
- (e) means for opening said current interrupting contacts acting through said spring in a direction to increase its biasing force to overcome the biasing force exerted on said current interrupting contacts by said insulating gas and including:
- (1) an endwise movable rod-like member operatively connected to one of said interrupting contacts, and
- (2) an endwise movable operating member having the spring providing a mechanical connection between it and said rod-like member whereby on movement of said operating member in a contact opening direction said spring is further stressed.
14. The invention, as set forth in claim 13, wherein the operating member is tubular, is telescoped over the rod-like member, and the spring is a coil compression spring telescoped over said tubular operating member and reacting at one end against radial flange means on said tubular operating member and at the other end against detent means extending radially from said rod-like member through slot means in said tubular operating member.
15. The invention, as set forth in claim 13, wherein a lost motion connection is provided between the rod-like member and the one interrupting contact.
16. The invention, as set forth in claim 13, wherein the rod-like member is directly connected to and movable conjointly with the one interrupting contact.
17. The invention, as set forth in claim 1, wherein:
- (a) a first bellows is provided between one of the interrupting contacts and the vacuum housing against which pressure exerted by the insulating gas in the housing acts to bias said one interrupting contact to the closed position,
- (b) the means for opening the interrupting contact includes an endwise movable rod-like member subject to atmospheric pressure and operatively connected to said one interrupting contact to move it to open position, and
- (c) a second bellows is provided between said rod-like member and the gas tight insulating housing with said pressure exerted by said insulating gas acting against one side and atmospheric pressure acting against the other side to provide a force dependent on the differential between said pressures to bias said rod-like member in a direction to move said one interrupting contact toward its open position.
18. The invention, as set forth in claim 1, wherein:
- (a) at least two vacuum type interrupter units are connected in series between the terminals of the insulating housing and the insulating gas therein acts to

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maintain a voltage withstandability between the terminals of and over the surface of the vacuum housings matching the voltage withstandability of the gaps between their respective contacts whereby flashover of individual interrupter units is unlikely on separation of the respective contacts, and

(b) means are provided for substantially simultaneously opening the interrupting contacts thereof.

19. The invention, as set forth in claim 18, wherein:

(a) the pressure exerted by the insulating gas in the housing biases each set of interrupting contacts toward its closed position, and

(b) lost motion connections are provided between the interrupting contacts and the means for opening the same to make the contact pressure of the interrupting contacts in the closed position independent of the force acting on the rod-like member.

20. A circuit interrupter comprising:

(a) a tubular gas tight insulating housing having terminals at its ends,

(b) a vacuum type interrupter in said housing having separable current interrupting contacts in a vacuum housing connected respectively to said terminals,

(c) an insulating gas in said tubular gas tight housing immersing said vacuum housing and characterized by providing dielectric strength substantially greater than the dielectric strength of air at atmospheric pressure and biasing said current interrupting contacts toward their closed position,

(d) a spring for biasing said current interrupting contacts toward their open position, and

(e) means for opening said current interrupting contacts acting through said spring in a direction to further stress it and to increase its biasing force to overcome the biasing force exerted on said current interrupting contacts by said insulating gas.

21. A circuit interrupter comprising:

(a) a tubular gas tight insulating housing having terminals at its ends,

(b) a vacuum type interrupter in said housing having separable current interrupting contacts in a vacuum housing connected respectively to said terminals and characterized by requiring a relatively short relative movement of said contacts between closed and open position,

(c) an insulating gas in said tubular gas tight housing immersing said vacuum housing and characterized by providing dielectric strength substantially greater than the dielectric strength of air at atmospheric pressure and biasing said current interrupting contacts toward their closed position,

(d) an operating member movable through a relatively long distance as compared to said relatively short movement of said contacts,

(e) means for moving said operating member through said relatively long distance, and

(f) spring means interposed between said operating member and one of said contacts in said vacuum type interrupter, said spring means acting to open said contacts at first with a force less than the force exerted by said insulating gas to close said contacts,

(g) said means for moving said operating member through said relatively long distance subsequently acting through said spring means for a substantial part of its movement before moving said contacts and during another part of its movement to open said contacts.

22. A circuit interrupter comprising:

(a) a tubular gas tight insulating housing having terminals at its ends,

(b) a vacuum type interrupter in said housing having separable current interrupting contacts in a vacuum housing connected respectively to said ter-

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minals and characterized by requiring a relatively short relative movement of said contacts between closed and open position,

(c) an insulating gas in said tubular gas tight housing immersing said vacuum housing and characterized by providing dielectric strength substantially greater than the dielectric strength of air at atmospheric pressure and biasing said current interrupting contacts toward their closed position,

(d) an operating member movable through a relatively long distance as compared to said relatively short movement of said contacts,

(e) means for moving said operating member through said relatively long distance,

(f) spring means interposed between said operating member and one of said contacts in said vacuum type interrupter, said spring means acting to open said contacts at first with a force less than the force exerted by said insulating gas to close said contacts,

(g) said means for moving said operating member through said relatively long distance subsequently acting through said spring means for a substantial part of its movement before moving said contacts and during another part of its movement to open said contacts, and

(h) means providing a lost motion connection between said spring means and said contacts whereby the force acting to hold said contacts closed is independent of the force exerted by said spring means.

23. A circuit interrupter comprising:

(a) a tubular gas tight insulating housing having terminals at its ends,

(b) a vacuum type interrupter in said housing having separable current interrupting contacts in a vacuum housing connected respectively to said terminals,

(c) an insulating gas in said tubular gas tight housing immersing said vacuum housing characterized by providing dielectric strength substantially greater than the dielectric strength of air at atmospheric pressure and biasing said current interrupting contacts toward their closed position,

(d) means for opening said current interrupting contacts and subject to atmospheric pressure,

(e) a first bellows between one of said interrupting contacts and said vacuum housing against which pressure exerted by said insulating gas in said insulating housing acts to bias said one interrupting contact to the closed position, and

(f) a second bellows between said contact opening means and said gas tight insulating housing with the pressure exerted by said insulating gas acting against one side and atmospheric pressure acting against the other side,

(g) the relation between the effective areas of said first and second bellows, the pressure exerted by said insulating gas and atmospheric pressure being such that a predetermined force is thereby required to open said current interrupting contacts.

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