A coaxial conductor connector for allowing connection from a low pressure ambient to the high pressure interior of a circuit breaker operated in response to connection of high voltage, high current pulses to our impulse coil in the high-pressure interior of the breaker. The gland permits easy connection and disconnection of the coaxial cable and maintains a pressure seal of the circuit breaker housing when the cable is connected.
COAXIAL CONDUCTOR CONNECTOR AND GLAND FOR TWO-PRESSURE CIRCUIT BREAKER RELATED APPLICATIONS

This application is an improvement of copending U.S. application Ser. No. 823,115, filed May 8, 1969, now U.S. Pat. No. 3,614,557 in the name of Otto Jensen, entitled GAS BLAST CIRCUIT INTERRUPTER USING MAIN MOVABLE CONTACT AS BLAST VALVE; and is also related to copending U.S. application Ser. No. 257,337, filed May 26, 1972, in the name of Rolf Mockli, entitled GAS BLAST SYNCHRONOUS BREAKER WITH GAS BIASED CONTACTS; Ser. No. 234,893, filed Mar. 15, 1972, in the name of Lorne D. McConnell, entitled INFLATED VALVE SEAT FOR SYNCHRONOUS BREAKERS; and Ser. No. 234,578, filed Mar. 14, 1972, in the name of Lorne D. McConnell, entitled CLOSED CHAMBER WITHIN MOVING CONTACT; all of which are assigned to the assignee of the present invention.

BACKGROUND OF THE INVENTION

This invention relates to synchronous circuit breakers, and more specifically relates to a novel coaxial cable connection with can be introduced into the high pressure container of a gas blast synchronous circuit breaker for introducing operating impulses into the breaker interior.

A two-pressure synchronous circuit breaker of the type shown, for example, in copending U.S. application Ser. No. 257,337 contains, in the high pressure region thereof, an impulse coil which is to be energized by a pulse in order to initiate the operation of the circuit breaker. At the same time, an isolating transformer is contained within the high-pressure gas system so that it can be kept relatively small in size. It is now necessary to bring an impulse signal into the high-pressure region containing the isolating transformer so that it is necessary to bring a coaxial cable, by way of example, through the high-pressure housing. It is also necessary to allow convenient connection of the coaxial cable section coming from the isolating transformer to the coaxial cable coming from the impulse voltage source.

BRIEF SUMMARY OF THE INVENTION

A novel coaxial cable connector and gland is provided which can be clamped onto a hollow tube entering the chamber of the circuit breaker. The connector employs sections which can be bolted together, with the center cable of each of the coaxial conductors to be joined carrying mating conical surfaces which are connected together under pressure. The entire joint may then be bolted to the end of the tubular member entering the high-pressure system to form a total pressure seal across the entire tubular member.

The novel connector and gland of the invention allow for ready connection and disconnection of the coaxial lead entering the pressurized chamber of the breaker and the inner end of the assembly is small enough to pass readily through the tubular port in the chamber. The system further provides, as described above, a positive gas-tight seal of the connector to the chamber as well as gas-tight seals within the coaxial leads themselves.

The connector provides high insulation capability equal to that of the coaxial cable itself, for example, approximately 17 KV R.M.S. withstand. The connector is also capable of conducting a high momentary through current. For example, the connector can carry oscillatory capacitor discharge currents of up to 10,000 amperes peak.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of one installation of a three-phase breaker using the concepts of the present invention.

FIG. 2 is a diagrammatic cross-sectional view of one of the poles of FIG. 1, and is shown to illustrate the controls and housing of the breaker pole.

FIGS. 3a and 3b are detailed cross-sectional views through the interrupting portion of the pole of FIG. 2, and illustrate the details of the construction of the novel breaker of the invention, with the breaker in the open and closed positions, respectively.

FIG. 4 is a plan view of the outer contact ring support of FIGS. 3a and 3b.

FIG. 5 is a cross-sectional view of FIG. 4 taken across the section line 5-5 in FIG. 4.

FIG. 6 is a front plan view of the outer contact plate of FIGS. 3a and 3b.

FIG. 7 is a cross-sectional view of FIG. 6 taken across the section line 7-7 in FIG. 6.

FIG. 8 is a front plan view of the outer sealing ring of FIGS. 3a and 3b.

FIG. 9 is a cross-sectional view of FIG. 8 taken across the section line 9-9 in FIG. 8.

FIG. 10 is a front plan view of one of the spacer plates of FIGS. 3a and 3b.

FIG. 11 is a cross-sectional view of FIG. 10 taken across the section line 11-11 in FIG. 10.

FIG. 12 is a plan view of a support casting for supporting the main movable contact of the breaker of FIGS. 3a and 3b.

FIG. 13 is a cross-sectional view of FIG. 12 taken across the section line 13-13 in FIG. 12.

FIG. 14 is a plan view of an aluminum casting connected to one of the main aluminum cylinders in FIGS. 3a and 3b.

FIG. 15 is a cross-sectional view of FIG. 14 taken across the section line 15-15 in FIG. 14.

FIG. 16 is a plan view of a seal retaining ring member used in the device of FIGS. 3a and 3b.

FIG. 17 is a cross-sectional view of FIG. 16 taken across the section line 17-17 in FIG. 16.

FIG. 18 is a front plan view of the inner piston guide structure of FIGS. 3a and 3b.

FIG. 19 is a cross-sectional view of FIG. 18 taken across the section line 17-17 in FIG. 18.

FIG. 20 is a cross-sectional view of the seal support ring used for the inflatable seal which cooperates with the movable arcing contact in FIGS. 3a and 3b.

FIG. 20a is an enlarged view of a portion of the seal support of FIG. 20.

FIG. 21 shows the flexible mounted seal support ring of FIG. 20 in FIGS. 3a and 3b.

FIG. 22 is a plan view of the main segmented contact ring of FIGS. 3a and 3b.

FIG. 23 is an enlarged view of a few of the contact elements of the contact ring of FIG. 22.

FIG. 24 is a side view of one of the contact elements of FIG. 23.

FIG. 25 shows a cross-sectional view of the coaxial cable connector and gland as connected to the tubular
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input port of the high-pressure chamber of the circuit breaker of FIGS. 3a and 3b.

FIG. 26 is a plan view of the main face of the outer connector section of FIG. 25.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring first to FIG. 1, there is schematically illustrated a three-phase, high power circuit breaker intended for use in an open bus system. Thus, the circuit breaker consists of three poles 10, 11 and 12 which are mounted on a platform 13, used in order to bring the poles 10, 11 and 12 up to the height of a particular open bus installation. A control cabinet 14 containing all necessary electrical controls including compressors, gas supply, and the like, is coupled to the individual poles 10, 11 and 12 through a control conduit 15 in any conventional desired manner. Each of the poles 10, 11 and 12 are carried in their own support housings 16, 17 and 18, respectively, and contain terminal pairs 19-20, 21-22 and 23-24, respectively, which are adapted to connect the bus leading from a generator, for example, to a load circuit.

Each of the poles of FIG. 1 may generally consist of the structure schematically illustrated in FIG. 2 for the case of pole 10. Note that FIG. 2 is intended to show an over-view of the breaker pole and illustrates in line-diagram fashion the manner in which electrical and hydraulic controls are connected to the pole. FIGS. 3a and 3b, to be described later, show the detail of the pole contact structure which is only schematically shown in FIG. 2.

Thus, in FIG. 2, the terminals 19 and 20 consist of conductive bus connector terminal members 30 and 31, which have conductive fins 32 and 33 extending therefrom. Terminals 30 and 31 are then connected to end caps 34 and 35, respectively, which are connected to the opposite ends of an elongated insulation housing tube 36. A stationary contact structure 40, to be later described in detail in FIGS. 3a and 3b, is connected to a hollow conductive tube 41, for example, of aluminum, and tube 41 is in turn connected to end cap 34 and terminal 30. A movable contact structure 42, which cooperates with stationary contact 40, is similarly connected to a hollow conductive tube 43 which is, in turn, connected to end cap 35 and terminal 31.

In addition to the connection of contact structures 40 and 42 to the end caps 34 and 35 by conductive tubes 41 and 43, respectively, heat pipes 44 and 45 are also coupled from the stationary and movable contact structures 40 and 42, respectively, to end caps 34 and 35, respectively, in order to rapidly conduct heat away from the contact structures and from the interior of the breaker. Heat pipes 44 and 45 may be of the well-known type in which a vaporizable fluid is moved from one end of the pipe to another end by capillary action, thereby to substantially decrease the temperature gradient between the ends of the pipe. Note further that the heat pipes 44 and 45 are disposed centrally and generally along the axis of the breaker pole and do not generally interfere with the assembly or construction of the main breaker components. Note further that heat pipe 44 may extend through an isolating transformer structure 46, which will be described more fully hereinafter.

The elongated insulation tube 36 is provided with integral flanges 47 and 48 which serve to receive clamping members 49 and 50 which allow the clamping of the insulation housing 36 within the main pole housing 16. Further integral flanges 51 and 52 allow the clamping of skirted insulation rings 53 and 54 on the insulation housing 36. Suitable current transformers 55 and 56 may then be mounted on the insulation cylinders 53 and 54, respectively.

As will be seen more fully hereinafter with reference to FIGS. 3a and 3b, the stationary and movable contact structures 40 and 42, respectively, serve as a valve section in a barrier between the right-hand and left-hand portions of the interior of the breaker as well as the breaker contacts. Thus, the left-hand portion of the breaker, that is, to the left of contacts 40 and 42, in general, will be filled with sulfur hexafluoride, for example, under relatively high pressure, for example, 14 to 17 atmospheres (200 to 250 p.s.i.g.). This left-hand high-pressure chamber communicates with conduit 57 in a suitable gas supply system. The right-hand side of the breaker is held at relatively low pressure, for example, 2 to 3 atmospheres of sulfur hexafluoride gas (30 to 45 p.s.i.g.), with the right-hand section of the chamber connected to the gas supply system through conduit 58.

It will be apparent that conduits 57 and 58 will be connected to a suitable compressor and gas filters in order to maintain the necessary pressure differential between the two chambers.

Once the main contacts are open, a downstream cut-off valve, schematically shown in FIG. 2 as the slide valve 59, closes to cut off volume 59a from the remainder of the low-pressure volume. This volume is proportioned to assure adequate gas flow to effect interruption. This volume remains communicated with the high pressure in the open position. Both contact gaps are thus insulated by high-pressure gas providing high dielectric integrity across the open breaker.

Another important feature of the structure of FIG. 2 is that, once the contacts begin to open, the movable contact is further strongly gas-biased by an initial exposure to the high-pressure system, as will be later described. This feature allows the use of synchronous operating techniques for operating the breaker, whereby the breaker interrupter contacts open just prior to a current zero. Thus, the contacts are subjected to very reduced arcing duty.

The novel synchronous operating mechanism will be described hereinafter in connection with FIGS. 3a and 3b, but the control circuitry is illustrated in FIG. 2. This circuitry includes a suitable synchronous pulse generator 60, shown in block diagram form in FIG. 2, which could take the form shown in U.S. Pat. No. 3,573,548 in the name of Bachofen, entitled CURRENT ZERO ANTICIPATING DEVICE, and assigned to the assignee of the present invention. Thus, the synchronous pulse generator 60 is suitably coupled to the circuit being protected and connected, for example, at terminals 19 and 20 and generates a pulse output immediately prior to a current zero following some input signal directing that the circuit breaker should be opened. The output of generator 60 is then connected to the control electrode of a triggered spark gap 61 which causes the gap to fire, thereby to allow the discharge of a charged bank of capacitors 62 into the primary winding of an isolating transformer 46.

A novel coaxial connection for carrying the discharge current of capacitors 62 into the interiorly disposed isolating transformer 46 is provided, as will be
later described. The secondary winding of the isolating transformer 46 is then connected by a coaxial conductor to operating system which will be electrically described in connection with FIGS. 3a and 3b, which causes the initial opening of the movable contact at a time just prior to the current zero in the system.

There is also provided, in FIG. 2, a high-speed, three-way gas valve 63 which may be of the type shown in U.S. Pat. No. 3,548,877, and which is operable selectively to connect conduit 64 to high gas pressure, or to low-pressure conduit 65 in order to operate the circuit breaker, as will be later described.

FIGS. 3a and 3b show, in detail, the contact mechanism and support therethrough used in the pole shown in FIG. 2. In FIGS. 3a and 3b, the pole is shown with a center line, with substantially all components being circularly developed around this center line. The breaker contacts are shown in their open position in FIG. 3a and in their closed position in FIG. 3b.

A first main conductive support body contained within the insulation cylinder 36 consists of the outer contact ring support 70. Outer contact ring support 70 is shown separately in FIGS. 4 and 5 so that its outline can be more clearly followed. It will be noted that the support 70 contains a plurality of axially directed openings, such as openings 71 and 72, which surround a central opening 73. In addition, support 70 contains a radial opening 74 which permits high-pressure gas to communicate from the high-pressure conduit 57 through the support 70 and into regions to the left of support 70. The openings, such as openings 71 and 72, permit this high-pressure gas from conduit 57 to pass to the right of support 70.

Support 70 is then bolted to a bolt ring 75 which, in turn, is welded to the right-hand side of conductive cylinder 41. The ring 70 is further tightly fitted within the interior diameter of tube 36, as illustrated.

A reset piston support body 80 is then fitted into the central opening 73 of support 70 and is bolted thereto by suitable bolts, such as bolts 81, shown in FIGS. 3a and 3b. A reclosing piston 82, shown in the open position in FIG. 3a and in its closing position in FIG. 3b, is then fitted within the piston support body 80 with suitable sealing rings disposed between its interior and exterior sliding surfaces.

The reclosing piston 82 has a leftwardly extending flange surface 83 which is supported over an inwardly extending neck 84 of a piston support end cap 85, which is suitably bolted to the reclosing piston support body 80. The body 85 further contains a rubber reset stop ring 86 which receives the left-hand end of neck 83 when the piston 82 is reset in the contact open position of FIG. 3a. The piston 82 further contains a rightwardly extending operating shaft 87, which is to be seen hereinafter, is used to mechanically close the interrupter contact of the breaker. Note that shaft 87 contains apertures 87a and 87b which are connected to a low-pressure region exterior of shaft 87.

In order to operate the piston 82, a conduit 88, which can be connected to high or low pressure by operation of valve 63, is connected to the right-hand surface of piston 82. A conduit 89 and the left-hand surface of piston 82 are always connected to low pressure.

Thus, conduit 88 is connected, through suitable channels in ring support 70, to the interior of a hollow support rod 90 which is, in turn, connected to input channel 64, which is, in turn, connected to the three-way valve 63, as shown in FIG. 2. In an analogous manner, the conduit 89 is connected through the hollow insulating support rod 91 through other channels which will be described hereinafter and ultimately to the input channel 65, which is, again, connected to the three-way valve 63. Accordingly, by suitable operation of the three-way valve 63, channel 88 will be at high pressure or low pressure (and channel 89 remains at low pressure) in order to move the piston 82 to the left, as shown in FIG. 3a. Piston 82 is returned to the position of FIG. 3b by high pressure forces applied during the closing operation, as will be later described.

An outer stationary contact plate 95 is then bolted to the right-hand end of contact support 70. Plate 95 is shown in FIGS. 6 and 7, where it is seen that there are a plurality of bolt pole openings about its periphery for receiving bolts, such as bolts 95a and 95b in FIGS. 3a and 3b for making bolt connection to the support 70. The contact plate 95 defines a radial contact surface 96, which will be seen more fully hereinafter, to slidably receive the main movable contact of the breaker.

Plate 95 further contains channels, such as channels 97 and 98, which are in communication with appropriate openings, such as openings 72 and 71, respectively, in support 70, where the openings, such as openings 97 and 98 in plate 95 allow high-pressure gas from contact 57 to appear to the right of the plate 95.

An impulse coil, which is used in the electrodynamic drive system, is then supported between contact plate 95 and support 80 and is formed of the composite structure including the insulation ring 100, which carries the spirally wound impulse coil winding 101. More specifically, winding 101 may consist, for example, of a spirally wound flat conductor, of for example, 23 turns of flat epoxy coated wire. Filament wound epoxy support rings 102 and 103 are embedded in insulation ring 100 to provide strong mechanical support for the coil 101 and, in a similar manner, an outer filament wound epoxy ring 104 contains the outer diameter of insulation body 100.

The start and finish of winding 101 is then connected to insulated leads, shown partly in dotted lines, as leads 105 and 106, which are taken through suitable openings in insulated body 100. The leads 105 and 106 will be noted to be coaxial leads as they extend from the isolating transformer 46 of FIG. 2 and remain coaxial until they reach the insulation ring 100. Note that these leads may extend through a suitable opening in the support body 80.

The outer contact plate 95 further carries, at its inner diameter, a contact ring 110 which is conventionally formed of inwardly biased contact segments, where the contact 110 mates sliding contact with the movable arcing contact, as will be later described. The contact 110 is held in position on the contact plate 95 by a contact clamping ring and guide 111 which is appropriately bolted to the contact plate 95.

The movable arcing contact 112 is then slidably received on the interior diameter of contact 110. The movable arcing contact 112 is shown in its disengaged position in FIG. 3a and in its engaged position in FIG. 3b, and is formed of a conductive main sleeve body 113 forming an internal cavity and has an inwardly directed flange 114 and an outwardly directed end flange 115. The inwardly directed flange 114 threadably receives an inner arcing electrode extension 114a which has an arcing tip 116. Note that the left-hand end of central
member 115 is engageable by the right-hand end of extension 87 of piston 82. The flange 115, as will be described more fully hereinafter, serves as a shorted winding which is closely coupled to impulse winding 101 when the arcing contact is in the closed position. Thus, if the impulse winding 101 is energized while the contact is in the closed position shown in FIG. 3a, extremely high magnetic forces arise, which rapidly move the movable arcing contact 112 to the left.

A buffer 117 is contained in the support body 80 and damps the impact of the movable arcing contact 112 when it reaches its fully open position in FIG. 3a. Further, the pressure differential across contact 112, due to high pressure on its right-hand face and low pressure on its left-hand face, serves to bias the contact in the open position, holding it positively in the full open position and preventing any rebound. The extreme right-hand end of contact 112 then contains an orifice-shaped, inwardly bent arcing contact tip 118, which will be described more fully hereinafter. Note further that the orifice 118 leads to the closed volume or internal cavity formed within the interior of the movable contact 112, thereby to enable gas blast into the interior of the contact, thereby to allow axial gas flow in two directions, as will be later described.

All of the above-described structure in Figs. 3a and 3b is generally supported from the main outer contact ring support 70. Spaced from this structure is the structure which carries the main movable contact and the stationary arcing contact, to be more fully described hereinafter. This structure generally includes an outer sealing ring 130 which is fitted within the tube 36 and contains a lower aperture 131 and a central annular depression 132, as further shown in Figs. 8 and 9.

Sealing ring 130 has a protruding notch 133 extending from the side thereof which rests into an annular notch in the side of the spacer plate 134. The spacer plate 134 is spaced from spacer plate 135 which is contained on support 70 and the spacer plates 134 and 135 are held apart by spacer rods including rods 90 and 91. A plurality of spacer rods, similar to rods 90 and 91, are mounted around the periphery of the spacer plates 134 and 135. By way of example, the spacer plate 135 is shown in Figs. 10 and 11 and is constructed of aluminum and contains a plurality of openings around the side surface thereof including openings 138 and 139. The facing surface of spacer plate 134 will have similar openings disposed therein, with a plurality of insulation spacer rods, such as rods 90 and 91 being captured between opposing pairs of openings in the spacer plates 134 and 135. The spacer rods themselves may be epoxy glass rods having central channels so that certain of the rods may conduct gas as a part of the gas control system for operating the breaker, as was previously referred to.

The casting 140 is shown by itself in Figs. 12 and 13 and it will be seen that the casting contains a plurality of L-shaped openings 141 through 146. It will be seen more fully hereinafter that L-shaped openings 141 to 146 are in the channel through which high-pressure gas flows to the low-pressure region during the closing operation. A further L-shaped opening 147 is provided in casting 140 and communicates between conduit 65 and the low-pressure region of the breaker to act as a discharge passage to discharge the high-pressure gas from volume 59a during the closing of the breaker.

The casting 140, as best shown in Fig. 13, further contains a plurality of openings including funnel-shaped openings 148 and 149 extending radially through the left-hand end of the member 140. It will be seen that these openings permit control of gas pressure on the main movable contact from conduit 64 when the three-way valve 63 is operated.

The adapter casting then receives, on its left-hand end, a piston stop member 150 which is a simple ring bolted into the left-hand end of adapter 140. The piston stop member 150 carries a sliding seal ring 151 and a rubber stop ring 152.

A ring 160, best shown in Figs. 14 and 15, is welded to the end of aluminum cylinder 43 and is provided with internal notches 161 to 166. These notches are generally aligned with openings 141 through 146, respectively, in adapter 140 of Figs. 12 and 13.

A further notch 167 is also provided in member 160 and is in alignment with opening 147 of member 140. Thus, the openings 141 through 147 of member 140 are in communication with the volume within the main low-pressure region within conductive cylinder 43.

For ease of manufacturing, a second ring-shaped member 170, having notched sections in alignment with the notches 161 to 167 of member 160 is clamped between member 160 and the right-hand end of member 140.

A seal retainer ring 171 is then disposed within ring 170 and is bolted to the right-hand end of an inner piston guide casting 172, which will be later described. The right-hand surface of ring 171 has a plate 171a welded therein across to prevent gas flow through the region in the interior of ring 171. The body of seal retainer 171 is machined from an aluminum casting and contains a series of bolt openings which receive bolts, such as bolts 173 and 174, which are bolted into member 172. Ring 171 then receives a seal retainer insert 175 which consists of an aluminum ring having a plurality of individual channels, such as channels 176 and 177 therethrough.

Each of the individual openings, such as openings 176 and 177 are connected together by an annular channel 178 in one wall of the ring 175. Ring 175 is better illustrated in Figs. 16 and 17 which more clearly show the channel 178 which joins the openings 176, 177 along with additional openings 179 to 182. It should also be noted that the main ring member 171 contains a passageway therein, shown in Figs. 3a and 3b as the passageway 190, which communicates with the annular channel 178.

A ring-shaped piston seal member having a generally U shape in section, shown as ring 191 in Figs. 3a and 3b, is then captured under the seal retainer 175, with the inner periphery of ring 191 being under pressure from member 172 while the outer diameter region of seal 191 is under pressure from the member 147. The seal 191 is of a flexible material, such as rubber, and may be inflated by gas under pressure which is connected beneath the seal by gas admitted to channel 190, and thus into the openings, such as openings 176 and 177 in the seal retainer 175. Thus, the seal 191 may be inflated in order to achieve a good seal relative to the main movable piston member attached to the movable contact independently of seal wear and permanent seal deformation, as will be later described.

The inner piston guide casting 172 is shown in detail in Figs. 18 and 19 and is held in position from the ring
9 171, thereby to be supported ultimately from the outer housing 36. It will be noted that a gas conducting conduit 200 is formed in the member 172 with the channel 200 ultimately to the left of FIG. 3b, the area immediately adjacent plate 95 including opening 98. Thus, high-pressure gas is applied to the channel 200 so that high-pressure gas is available to inflate the seal 191.

FIGS. 18 and 19 also show the presence of radically directed openings 172a and 172b (FIG. 19) and further opening 172e in FIG. 3b. These radically directed openings form flow channels for the passage of high-pressure gas from the high pressure system during the interruption operation, with this gas continuing to flow through the aligned openings formed on members 170 and 160, described above.

A plurality of bolt openings including opening 201 are formed in member 172 to receive bolts which connect pivot ring 201a in position. Pivot ring 201a supports the flexible contacts of the stationary arcing contact structure, and also has bolted thereto the arcing contact ring 202. Arcing contact ring 202 has connected thereto a central arcing contact body 203. Arcing contact body 203 has an arcing ring tip 204, as shown.

As shown in FIGS. 3a and 3b, the member 172 also carries therein a rubber buffer ring 210, where the buffer ring 210 acts as a shock absorbing stop for the motion of the main piston 211. The main piston 211, which will be described more fully hereinafter, is supported on its exterior by the interior diameter of member 147 and contains a rightward extending portion 212 which serves as a downstream cutoff valve in cooperation with the inflatable seal 191. Thus, when the circuit breaker is in the open position of FIG. 3a, the right-hand most end of member 212 is pressed into form sealing engagement with flexible ring 191 which flexes in order to form a good gas-tight seal with the end of member 212, thereby enclosing the volume 59a of FIGS. 3a and 3b prior to the operation of interrupting contact 112. The main piston 211 is slidable supported by member 147, as previously indicated, with a sliding seal ring 213 disposed between these members, and is also slidable supported relative to member 172 with a sliding seal ring 214 disposed between members 172 and 212. A further sliding seal ring 215 is disposed between ring 150, which also slidable supports the left-hand outer diameter portion of piston 210.

The outer diameter of the main piston 211 has a contact ring 216 connected thereto which makes sliding contact engagement with surface 96 of contact plate 95. Contact ring 216 is of the segmented contact type, with the individual segments of the ring being spring-biased radially outwardly relative to one another in a manner well known to those skilled in the art. Thus, as shown in FIG. 22, the ring 216 consists of a plurality of individual segments, such as segments 300, 301, 302 and 303. These segments are shown in enlarged fashion in FIG. 23 to illustrate the presence of biasing spring means 304, 305, 306 and 307, respectively. Spring-biasing means 305 has been shown in some detail to illustrate the presence of biasing spring washers 308 and 309 carried on a button spacer 310, such that the fingers 300 and 301 are pressed away from each other. Each of the spring-biased elements will be constructed in this manner for each of the contact elements. Each of the contact elements also have bolt pole openings 315 to 318 and a notch section, shown for the case of finger 300 in FIG. 24 as notch 319.

The individual fingers are then individually and pivotally bolted into the end of main contact piston 211, as shown in FIGS. 3a and 3b, by the bolts 320 and 321 for contact fingers 300 and a further contact finger 322, respectively. Note that the main contact piston 211 contains an inwardly directed protrusion 323 which receives the notches of the contact fingers such as notch 319 of finger 300. This contact operation will be described more fully hereinafter.

The member 172 also receives an inner contact body 220 which is bolted thereto as by bolts 221 and 222 of a ring of bolts disposed circularly around the axis of inner contact body 220. The outer diameter 223 of inner contact body 220 also slidably receives the contact ring 216 attached to the main piston 211. The inner contact body 222 along with body 172 then serves to support the flexible arcing contact structure which cooperates with the movable arcing contact 112.

More specifically, a plurality of finger contacts extend around the interiors of bodies 172 and 220, two of which are shown in FIGS. 3a and 3b as the finger contacts 230 and 231. Typically, 18 such fingers may be disposed in a cylindrical cluster, each mounted in an identical manner between the members 172 and 220. In the case of contact fingers 230 and 231, the right-hand ends are captured beneath the flange 232 of member 201a and are pressed against the exterior of flange 232 by biasing springs 233 and 234, respectively.

The right-hand end of each of the contact fingers is then brazed to a flexible shunt, for example, flexible shunts 235a and 235b for contact fingers 230 and 231, respectively. These shunts are then connected to conductive member 172 by bolts, such as bolts 236 and 237, respectively. The left-hand ends of each of the contact segments are similarly pressed inwardly and toward one another by biasing springs 240 and 241, with these fingers also being pressed toward stops, such as stops 242 and 243 which control the inward motion of the fingers and thus the nozzle openings.

An intermediate plate 250 and contact guide plate 251 are then bolted to member 220. A flexible seal 252 is wrapped over a seal support ring 253 and is captured between plates 250 and 251. The seal support 253, which may be of brass, and the seal ring 252, are shown in cross-section in FIGS. 20 and 21, respectively, so that their structures can be more clearly understood. Note that plate 251 and plate 250 contain aligned openings, such as openings 260 and 261, respectively, which allow high-pressure gas, to the left of plate 250, to inflate the seal 252 through openings in seal support 253, such as the openings 253a and 253b shown in FIG. 20. Additional openings through the seal support may also be provided around the periphery of ring 253. Each of these openings are joined together by an annular channel 253c in the rear surface of support 253, as clearly shown in FIG. 20 as well as FIG. 20a, which is an enlarged view of channel 253c, where it receives opening 253a. In addition, it will be noted that there is a radial slot 253d leading from channel 253c and opening 253a to allow communication between opening 253a and the corresponding openings in plates 250 and 251.

The movable arcing contact contains a slightly raised annular protrusion 263 which cooperates with seal 252.
by pressing against the seal when the arcing contacts are engaged.

Each of the individual arcing fingers are then provided with arcing tips, such as arcing tips 265 and 266 for arcing contacts 230 and 231, respectively. The ring of arcing contacts on the individual contact fingers then engage the protruding nose terminating in orifice 118 of the contact 112 when the arcing contacts are closed.

It is now possible to consider the operation of the breaker shown in FIGS. 3a and 3b.

CURRENT PATH WHEN BREAKER CONTACTS ARE CLOSED

It is first assumed that the breaker contacts are in the closed position, as shown in FIG. 3a. In this closed position, the main contact of the interrupter, consisting of the contact ring 216 carried on main piston 211, is electrically connected between surface 96 of contact plate 95 and the outer surface of inner contact body 220. The arcing contacts are also engaged where, for example, the extending nose 118 of arcing contact 112 is in engagement with the contact fingers of the stationary arcing contact including contact fingers 230.

The main current carrying path thus consists of a path extending from one terminal of the pole of the breaker, for example, pole 19 in FIG. 2, to the conductive cylinder 41, to adapter 75, to member 80, to contact plate 95 from surface 96 of contact plate 95 into the contact fingers of main contact ring 216, from the other contact surface of the contact fingers of contact 216 into the inner contact member 220, conductive member 172, member 171, member 170, adapter ring 160, conductive tube 43 and thence out to the opposite terminal of the pole, such as terminal 20 of FIG. 2. A small parallel current flow exists through the interrupter or arcing contacts, including arcing contacts 110 and 112.

GAS PRESSURES WITH CONTACTS CLOSED

As pointed out previously, sulfur hexafluoride or some other suitable dielectric gas or mixtures thereof at high pressure, is connected to conduit 57 while a relatively low pressure gas is connected to conduit 58. Where SF₆ is used as the dielectric medium, conduit 57 might be at about 14 atmospheres, whereas conduit 58 might be at about 3 atmospheres. These two conduits are, of course, suitably connected to an appropriate compressor and filters (not shown) so that the two pressures can be suitably maintained. Similarly, an appropriate monitoring system may be used for monitoring pressures and temperatures of the gas in the breaker and operating the compressor in response to predetermined pressure and temperature conditions.

With the circuit breaker in its closed position, the "blast valve" formed between protrusion 263 of the interrupting contact 112 and inflated seal 252 is closed. In general, all spaces to the left of this valve in FIGS. 3a and 3b are at high pressure while those regions to the right are at low pressure. Note that the valve is formed immediately adjacent the cooperating interrupting contact surfaces so that, immediately upon interruption operation, gas flow is available to play radially through the arc. It will be further noted that the blast valve is formed between the interrupter contacts and the main contacts (contact ring 216 which bridges between members 95 and 220) so that the main circuit breaker contacts, which need not have interrupting capacity, are disposed in high pressure gas at all times. Thus, the maximum travel of the main movable contact ring 216 is decreased since high voltages can be supported by relatively short distances in SF₆ under pressure.

The high-pressure gas from conduit 57 fills the region surrounding spacer rods 90 and 91 and the channels, such as channel 74 in member 70 to fill the main high-pressure region 400. Note that the isolating transformer of FIG. 2 (not shown in FIGS. 3a and 3b) will be disposed in this high-pressure gas so that the transformer can be made relatively small, since points of relatively high voltage difference can be closer than they normally would be if the transformer was disposed in a lower pressure medium. A further conduit 401 (FIGS. 2 and 3a) is connected into the high-pressure region 400, but this conduit is used to conduct coaxial cable connectors to the isolating transformer and from the discharged capacitors 62 of FIG. 2, and the conduit 401 is normally closed to prevent escape of the high-pressure gas from region 400. This same high-pressure gas from conduit 57 appears on the right-hand surface of plate 95 communicating therewith through openings 97 and 98. The high-pressure gas is further prevented from seeping past the outside diameter of main piston 311 by the sliding seal 215.

Low-pressure gas from conduit 58 fills the low-pressure region 402, with this low-pressure extending through the components in members 160 and 170 and then through the openings, such as openings 141 in member 140 and then through the gap to the right of the open end of piston 211 which is now in seating engagement with sealing 191 through the openings, such as openings 172a and 172c in member 172 and then up to the valve formed between arcing contact 112 and seal 252.

Low-pressure gas also fills gas passages 89 and 91, which communicate at all times with low-pressure region 402. The volume to the left of member 82 is thus at low pressure, as is the region to the left of arcing contact 112 which communicates with the region within rod 87 through openings 87a and 87b.

Control pressures are also applied through the three-way valve 63 in FIG. 2, such that conduit 88 of FIGS. 3a and 3b is at high pressure, so that the piston 82 is retracted to its left-hand position, as shown in FIG. 3a. Moreover, while the breaker is closed, three-way valve 63 seals off the possible interconnection of conduits 64 and 65.

OPENING OPERATION

In order to open the breaker (from the position of FIG. 3b), a trip signal is first derived from some suitable relay source (not shown). This trip signal circuit is schematically illustrated in FIG. 2 as the trip circuit 410. Trip circuit 410 delivers a signal to the three-way valve 63 which is so arranged that, in FIG. 3a, conduit 64 is switched from low pressure (due to its prior connection to conduit 65) to high pressure and sealed off from conduit 65. The switch to high pressure in conduit 64 causes the application of high pressure against surface 412 of piston 211. At the same time, the high pressure against surface 411 of piston 211 is exhausted into low-pressure conduit 65.

Accordingly, the main piston 211 moves rapidly to the right, opening the main contact surfaces and com-
mutating the current through the breaker into the interrupter contacts. At the same time, the high pressure in conduit 64 allows piston 82 to retract to the left, thereby to unblock the interrupter contact 112 and leaving the interrupter contact 112 held in position solely by the contact biasing forces and frictional forces which hold contact 112 in its closed condition.

When pistons 82 and 211 move to the breaker open position, pressure in the operating valve manifold and conduit 64 builds up toward their full high pressure level. When this occurs, in a time of the order of 40 milliseconds, a pressure responsive switch is operated to energize the output circuit of the synchronous pulse generator 60. Output voltage pulses from this generator are then allowed, through suitable control circuitry, to cause the triggering of gap 61 of FIG. 2 and the discharge of capacitors 62 into the isolating transformer 46 and then into the impulse coil 101. Such pluses are delivered in the order of 1.5 milliseconds prior to the next upcoming primary current zero.

The pulse current in the impulse coil 101 then causes a strong electromagnetic repulsing force between coil 101 and the flange 115 of interrupter contact 112, so that the contact 112 begins to move to the left, thereby opening the seal between the circular valve seat 263 on interrupter contact 112 and the inflated valve seat 252. Note that at the time the seal breaks, that the arcing contact 118 and the arcing finger contacts including contacts 230 and 231 are still engaged. With the breaking of the seal, however, high-pressure gas surrounding the interrupter contact now bears against the right-hand surface of the interrupter contact contained within valve seat protrusion 263 so that a strong gas pressure force is immediately added to the electrolytic repulsion force caused by coil 101, thereby rapidly to accelerate the movable contact 112 toward its fully open position.

Once the arcing contacts separate and an arc is drawn, high-pressure gas, which has started to flow through the gap between the separating contacts as soon as the blast valve seal is opened between the seat 263 and seal 252, is immediately available and flowing through the arc. It should be noted that this gas flow is in two directions along the axis of the breaker since high-pressure gas can flow into the closed volume of contact 112, which was at low pressure, and can also flow to the right and toward the arcing contact tip 204. This two-directional flow of gas is advantageous in the interruption of the arc. It should also be noted that valve seat 253 is upstream of any arc products produced during blast of gas through the arcs and, therefore, will not be contaminated or subject to burning by the arc.

It will be noted that the specific components are preferably designed such that a gas blast is obtained about 0.5 milliseconds before current zero. This established gas blast will extinguish the current at the next current zero.

Gas flow continues until the closed volume 59a is filled with high pressure SF₆. Note that the separated contacts, including separated interrupter contacts 112 and the contact fingers 230 and 231 are held open in high-pressure gas and so that relatively small gaps can be used to support a relatively high line voltage.

Since the contacts are open just prior to a current zero, the arc energy is extremely limited, so that the breaker will also have excellent dielectric recovery interruption.

The system also employs advantageous mechanical-pneumatic damping structures. Thus, the piston 82 has its end motion damped by engaging the buffer 86. Similarly, the motion of contact 112 is ultimately damped by the buffer 117. Again, the motion of the third moving part—piston 212, is damped by buffer 210. Thus, rubber stops, which may be of any suitable material other than rubber, act to absorb a significant part of the kinetic energy of the moving components. In the case of the buffer 210 for piston 211, it will be noted that even any small recoil of piston 211 will be damped by the high-pressure gas acting on the surface 412 of the piston, which pressure also positively holds the piston in its contact open and valve sealed condition.

CLOSING OPERATION

In order to close the circuit breaker when it is in the open position shown in FIG. 3a, a closing signal is applied to the three-way valve 63, such that conduit 64 is connected to low-pressure conduit 65. Consequently, conduit 88 assumes a low pressure, so that the piston 82 is moved to the right with its extension 87 picking up movable contact 112 to move contact 112 to the right and toward its contact engaged position. At the same time, the pressure on surface 412 of piston 211 is reduced, so that the piston 211 is moved to the left and toward its contact closed position. Note that during this movement to the left, that the downstream cutoff valve formed by the engagement of sleeve 212 and seal 191 is open, thereby exhausting the high-pressure gas to the left of plate 171a and within volume 59a, and removing the pressure on the right-hand facing surface of the interrupter contact 112.

The interrupter contact 112 then closes prior to the closing of the main contact 216 carried on piston 211 and the system is then held in the closed position and is prepared for the next opening operation.

INTERNAL CAVITY IN MOVABLE CONTACT

In the specific design of interrupter contact 112, to obtain preferred dual axial flow of the high-pressure sulfur hexafluoride gas during interruption, the interior of the closed chamber within the contact should have a volume to permit flow of gas into the chamber during the relatively short arcing period. Since the breaker is a synchronous circuit breaker, this will be a relatively short arcing period, for example, 0.75 milliseconds, so that the interrupter contact closed volume can be relatively small.

The ability for gas to flow into the enclosed chamber within contact 112 will be controlled to a large measure by the opening size of orifice 118. Thus, the movable contact nozzle opening for orifice 118 could be from one-fourth inches to three-fourths inches, which would provide sonic flow capability time periods of from 22.5 milliseconds to 2.5 milliseconds, respectively, for filling the chamber.

In a preferred form of the contact construction, the internal chamber had a diameter of about 2-5/16 inches and an axial length of approximately 2 inches. The nozzle opening for the center of orifice 118 was approximately five-eighths of an inch. It was found that the use of the closed chamber to produce a dual axial flow of gas during interruption operation increased interrupting performance of the circuit breaker by from
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20 to 25 percent as compared to the same form of contact system tested without the auxiliary nozzle added to the movable contact.

COAXIAL CABLE CONNECTION AND GLAND

FIGS. 25 and 26 illustrate the structure which connects a coaxial cable from the capacitor bank 62 of FIG. 2 and into the isolation transformer 46 of FIG. 2. Referring to FIG. 25, there is illustrated a coaxial cable 430 which is fastened, for example, to the isolation transformer 46, and which must be taken out through the tubular member 401, to be connected to a coaxial cable section 431 coming from the capacitor bank 62 of FIG. 2. Both coaxial cables 430 and 431 may be identical in construction and consist generally of inner conductors 432 and 433, respectively, and outer conductors 434 and 435, respectively, with the inner and outer conductors spaced from one another by conventional insulation mediums.

FIG. 25 further shows that tubular member 401 terminates in an extending flange 440, which has a circle of bolt openings therethrough including bolt openings 441 and 442. In preparing the coaxial cables 430 and 431 for connection together in the novel connector of FIG. 25, a tubular connector 450 is connected to the interior conductor 432 of cable 430 and is provided with an end surface having an inwardly tapering conical depression. In a similar manner, the central conductor 433 of cable 431 has secured at its end a conical member 451, which has a mating outwardly tapered conical end surface which can make pressure connection with the inwardly tapering surface of connector 450. Both members 450 and 451 are of any suitable conductive material, such as copper.

A plastic sleeve 452, which may be of polytetrafluoroethylene, is formed on the coaxial cable 430 and nests over the connector 450 as shown. Moreover, the outer conductor 434 is bent outwardly and over the outer surface of insulation sleeve 452. In a similar manner, an insulation sleeve 453 is formed over the coaxial conductor 431, with member 453 being designed to nest into the end portion of member 452, as shown in FIG. 25.

The outer conductor 435 is also arranged to extend over the outer surface of member 453. A sealing ring 454 is then placed over insulation member 452, as shown, and a clamping plate 455, which may be of brass, is pressed over the cable 430 and has the outer conductor 434 connected thereto. A plurality of bolts, including bolts 456 and 457, bolts the member 455 to the adapter 460, thereby applying pressure against the seal 454. The adapter 460 is fitted over the coaxial cable 431 and the plastic sleeves 452 and 453 and compresses rubber gasket 461 against insulation sleeve 453 as shown.

As shown in FIG. 26, the adapter 460 has an enlarged flange 462 which contains a plurality of bolt openings, including bolt openings 463 and 464, which are aligned with the pole openings in flange 440, such as openings 441 and 442, respectively. Note that FIG. 26 also shows the position of threaded openings, such as openings 465 and 466 which receive the bolts 456 and 457, respectively, of FIG. 25.

A plurality of bolts, including bolts 470 and 471, are then used to bolt the flange 462 of member 460 to the flange 440 of member 401, with a sealing ring 472 being compressed between these two bodies.
pressure connection with one another, and means for clamping said end surfaces of said housings together; said end surfaces of said first and second adapters being pressed into contact by said first and second housing when said housings are clamped together, said pressurized enclosure having an opening therein, one of said housings having a flange extending therefrom; said connector being at least partly disposed within said opening with said flange secured to said enclosure and sealed around the periphery of said enclosure to prevent the escape of pressurized gas from said enclosure.

2. The device of claim 1 wherein an isolating transformer is disposed within said pressurized enclosure and is connected between said second coaxial conductor and said electrodynamic operating circuit.

3. The device of claim 1 wherein said end surfaces of said first and second conductive adapters are conical.

4. The device of claim 1 wherein said means for clamping said end surfaces of said housing consists of a ring of bolts.

5. The device of claim 1 which further includes first and second insulation sleeves disposed between said first and second housings and the central conductors of said first and second coaxial conductors respectively.

6. The device of claim 5 wherein said sleeves telescope relative to one another when said clamping means is clamped closed.

7. The device of claim 5 which further includes first and second seal means disposed between said first and second housings and said first and second sleeves respectively.

8. The device of claim 5 wherein said end surfaces of said first and second conductive adapters are conical.

9. A coaxial cable connector for introducing coaxial cable into the interior of a pressurized enclosure and through an opening in said enclosure and for connecting the opposite ends of first and second elongated, flexible coaxial cable conductors to one another; each of said coaxial cables containing elongated solid interior conductors of a constant cross-section and elongated outer conductors which surround their respective interior conductor and are insulated therefrom and supported therefrom by solid insulation sleeves; said connector comprising:

10. The device of claim 9 which further includes first and second insulation sleeves disposed between said first and second housings and said interior conductors of said first and second coaxial conductors respectively.

11. The device of claim 10 wherein said sleeves telescope relative to one another when said clamping means is clamped closed.

12. The device of claim 10 which further includes first and second seal means disposed between said first and second housings and said first and second sleeves respectively.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION
Patent No. 3,792,217 Dated February 12, 1974
Inventor(s) Lorne D. McConnell, Rolf Mockli

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 16, line 46, "second first and sec" should read --- said first and second ---

Column 17, line 4, "housing" should read --- housings ---
line 13, "si" should read --- is ---
line 18, "devic" should read --- device ---
line 19, "calmping" should read --- clamping ---

line 19, "housing" should read --- housings ---
line 27, "calmped" should read --- clamped ---

Signed and sealed this 5th day of November 1974.

(SEAL) Attest:
McCoy M. Gibson Jr. C. Marshall Dann
Attesting Officer Commissioner of Patents
UNITED STATES PATENT OFFICE
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