Oct. 7, 1969 P. BARKAN 3,471,666

AXIAL BLAST INTERRUPTER WITH ARC-ROTATING MEANS

Filed April 18, 1967 2 Sheets-Sheet 1

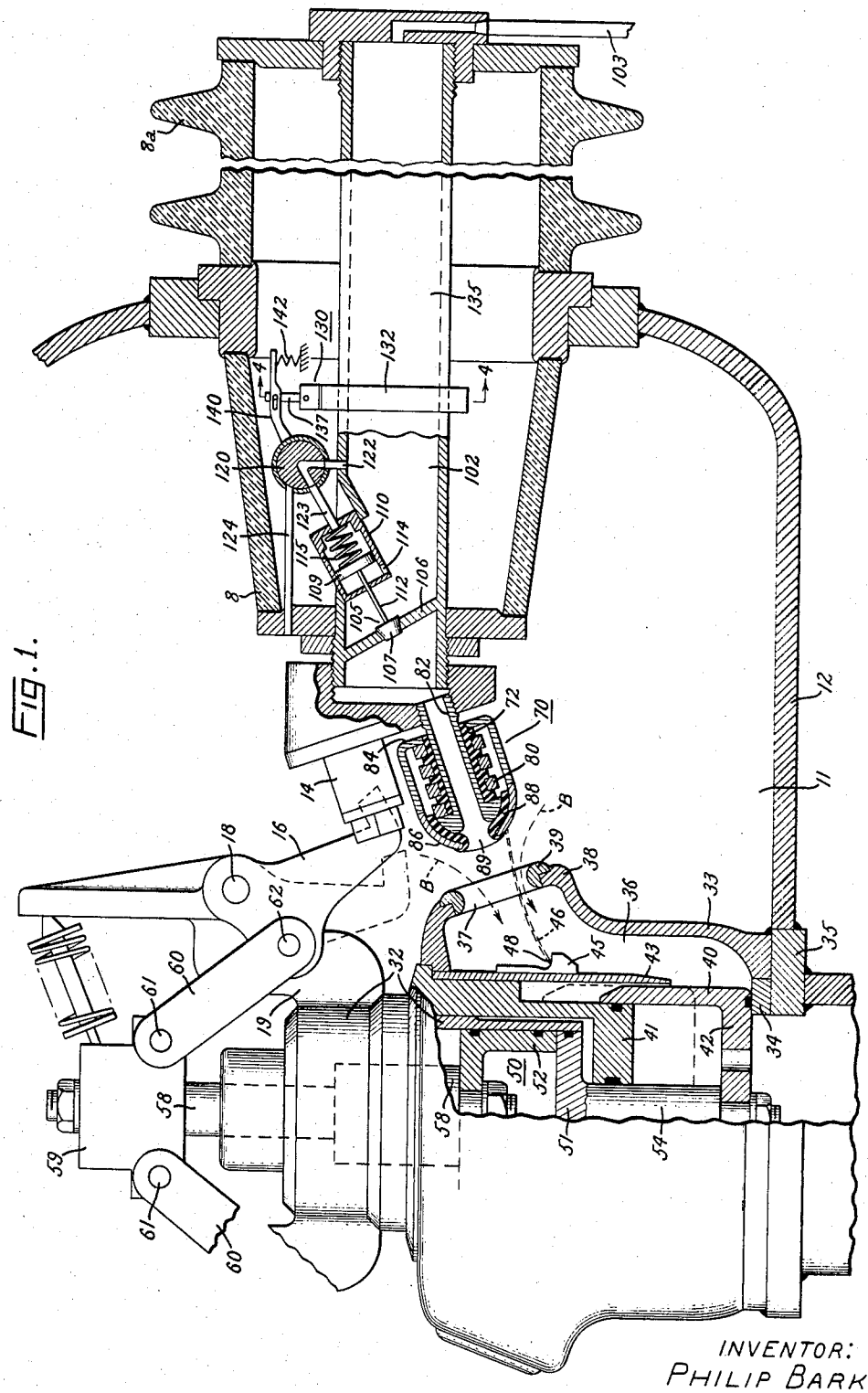


Fig. 1.

INVENTOR:
PHILIP BARKAN,
BY William Freedman
ATTORNEY

Oct. 7, 1969 P. BARKAN 3,471,666

AXIAL BLAST INTERRUPTER WITH ARC-ROTATING MEANS

Filed April 18, 1967 2 Sheets-Sheet 1

Fig. 2.

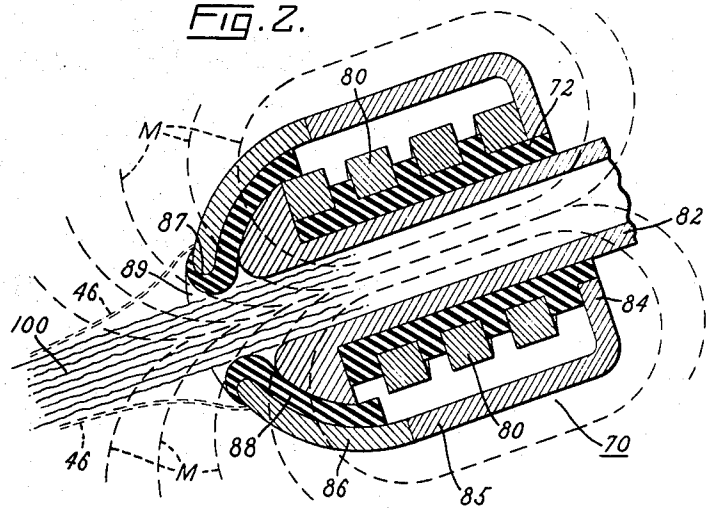


Fig. 3.

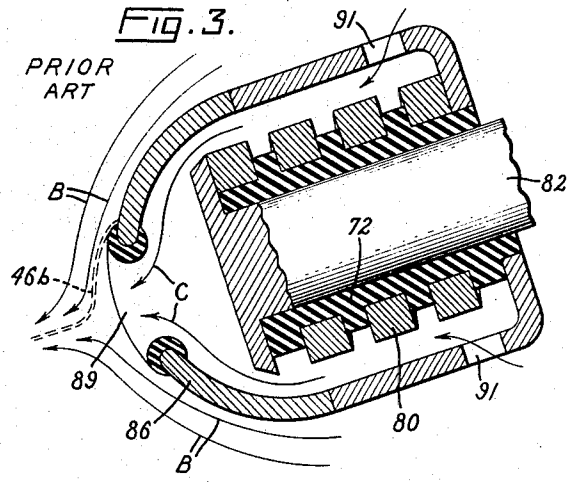


Fig. 4.

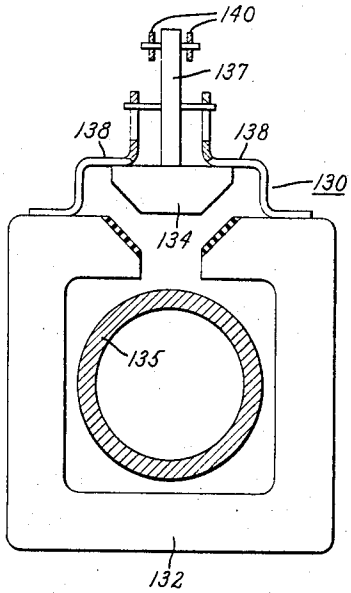
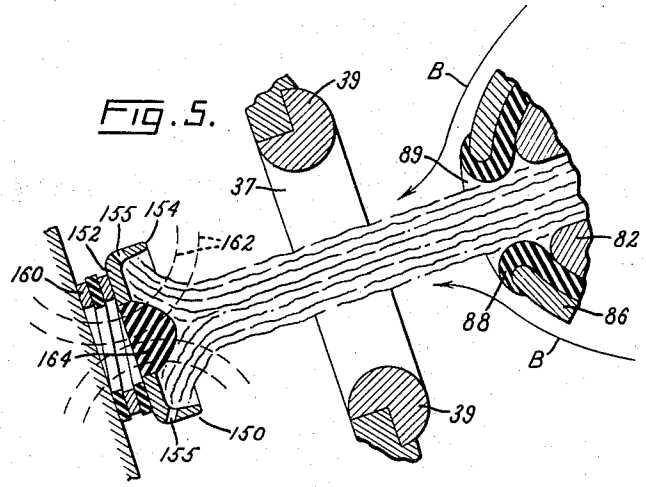


Fig. 5.



INVENTOR:
PHILIP BARKAN,

BY William Freedman
ATTORNEY

United States Patent Office 3,471,666
Patented Oct. 7, 1969

3,471,666

AXIAL BLAST INTERRUPTER WITH ARC-ROTATING MEANS

Philip Barkan, Media, Pa., assignor to General Electric Company, a corporation of New York

Filed Apr. 18, 1967, Ser. No. 631,835
Int. Cl. H01h 33/82, 9/44, 33/18
U.S. Cl. 200—148 8 Claims

ABSTRACT OF THE DISCLOSURE

An axial blast, gas blast circuit interrupter with magnetic means for creating a radial magnetic field to rotate the upstream arc terminal. To assure rotation of a major portion of the arc column, instead of merely the arc terminal, a gas jet of much higher velocity than the main axial blast is directed in a downstream direction along the longitudinal center line of the radial magnetic field. This high velocity jet overcomes the centering effect of the axial blast on the arc column and maintains the arc column in a postition where it can be effectively rotated by the radial magnetic field.

Background of the invention

This invention relates to an axial blast, gas blast circuit interrupter and, more particularly, relates to an axial blast interrupter that includes magnetic means for rotating the usual arc that is established during interruption.

The usual gas blast circuit interrupter comprises means for establishing an electric arc across a gap between two electrodes and means for directing a blast of gas into the arcing region. The purpose of the gas blast is to cool the arc and to scavenge the arcing region of arcing products so as to increase the rate at which dielectric strength is built up across the gap when the current zero point is reached. By increasing this rate of dielectric recovery, it is possible to improve the ability of the gap to withstand the usual recovery voltage transient which builds up as soon as current zero is reached, thus improving the interrupting ability of the circuit interrupter.

In an axial blast type of circuit interrupter, the gas blast first flows past one of the electrodes, referred to hereinafter as the upstream electrode, and then axially of the arc about its periphery. For improving the dielectric recovery rate in such an interrupter, it has been proposed in U.S. Patent 3,274,365-Beatty, assigned to the assignee of the present invention, that the upstream arc terminal be rotated about the central axis of the upstream electrode. This is done by a radial magnetic field having an axis that generally coincides with the central longitudinal axis of the interrupter. While some improvements can be obtained in this matter, I have found that a limitation is imposed by aerodynamic forces accompanying the axial blast. More specifically, the axial blast tends to center the arc column along the central longitudinal axis, and in this region the radial magnetic field is ineffective to produce arc rotation. Means is provided in the Beatty interrupter to hold the upstream terminal of the arc spaced from the central axis, but I have found that this means is not capable of holding the arc column itself spaced from the central axis. I have observed that the axial air blast tends to bend the arc column almost immediately into a position where it extends along the central axis. The net result is that only the arc terminal is rotated by the radial magnetic field, while the major portion of the column itself remains stationary.

Summary

An object of my invention is to provide means for forcing a major portion of the arc column in an axial blast circuit interrupter to rotate, despite the centering effect of the axial blast.

Another object is to effect the above rotation of the arc column during high current interruptions without impairing the ability of the circuit interrupter to interrupt capacitive currents.

In carrying out the invention of one form, I provide an axial-blast, gas-blast circuit interrupter comprising arc-rotating magnetic means for creating a radial magnetic field that has its longitudinal center line extending between the electrodes in the direction of the axial blast. A gas jet of much higher velocity than the main axial blast is directed in a downstream direction along the longitudinal center line of the radial magnetic field. This high velocity jet, which is surrounded by the main axial blast, overcomes the tendency of the main axial blast to center the arc column along the longitudinal axis of the radial magnetic field and maintains the arc column in a position where it can be effectively rotated by the radial magnetic field.

Brief description of drawings

For a better understanding of the invention, reference may be had to the following description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a sectional view of a gas blast circuit interrupter embodying one form of my invention.

FIG. 2 is an enlarged sectional view of the upstream electrode region of the interrupter of FIG. 1.

FIG. 3 schematically illustrates a prior art upstream electrode.

FIG. 4 is a sectional view along the line 4—4 of FIG. 2.

FIG. 5 is a partial sectional view of a modified embodiment of the invention.

Detailed description of preferred embodiment

Referring now to FIG. 1, the circuit interrupter shown therein is of the sustained-pressure, gas-blast type described and claimed in U.S. Patent 2,783,338-Beatty, assigned to the assignee of the present invention. Only those parts of the interrupter that are considered necessary to provide an understanding of the present invention have been shown in FIG. 1. In this respect, only the right hand portion of the interrupter has been shown in section inasmuch as the interrupter is generally symmetrical with respect to a vertical plane and the left hand portion is substantially identical to the right hand portion. As described in detail in the above-mentioned Beatty patent, the interrupter comprises a casing **12** which is normally filled with pressurized gas to define an interrupting chamber **11**. Located within the interrupting chamber **11** are a pair of relatively movable contacts **14** and **16** which can be separated to draw an arc within the pressurized gas within the chamber **11**. The contact **14** is relatively stationary, whereas the other contact **16** is mounted for pivotal motion about a fixed, current-carrying pivot **18**. Stationary contact **14** is mounted on the inner end of a high voltage terminal bushing **7** comprising two porcelain shells **8** and **8***a* and a conductive stud **135** extending therethrough. When movable contact **16** is driven clockwise about pivot **18** from its solid-line closed position of FIG. 1, an arc is established in the region where the contacts part. The movable contact **16** is shown by dotted lines in FIG. 1 in a partially-open position through which it passes during a circuit-interrupting operation after having established an arc.

Movable contact **16** is supported by means of its current-carrying pivot **18** on a conductive bracket **19** that is preferably formed integral with a stationary cylinder **32**. Cylinder **32** at its lower end is suitably supported from a generally cylindrical casting **33**. Casting **33** at its lower end is suitably secured to a flange **35** rigidly carried by the stationary metallic casing **12**.

For producing a gas blast to aid in extinguishing the arc, cylindrical casting **33** contains a normally-closed ex-

haust passage **36** leading from the interrupting chamber **11** to the surrounding atmosphere. Casting **33** at its upper end is provided with a tubular nozzle member **38** having an orifice portion **39** at its outer end defining an inlet **37** to the exhaust passage **36**. This inlet **37** is referred to hereinafter as the orifice opening. The flow of arc-extinguishing gas through tubular nozzle **38** and exhaust passage **36** is controlled by means of a cylindrically-shaped reciprocable blast valve member **40** located at the outer, or lower, end of exhaust passage **36**. This blast valve member **40** normally occupies a solid-line, closed position wherein a portion **42** at its lower end sealingly abuts against a stationary valve seat **34** carried by exhaust casting **33**.

During a circuit interrupting operation, movable blast valve member **40** is driven upwardly from its solid-line, closed position of FIG. 1 through a partially open intermediate position shown in dotted lines in FIG. 1. Opening of valve member **40** allows pressurized gas in the chamber **11** to flow at high speed through orifice opening **37** and nozzle **38** and out exhaust passageway **36** past valve member **40** to atmosphere, as indicated by the dotted line arrows B of FIG. 1. The manner in which the gas blast acts to extinguish the arc will soon be described in greater detail.

At its upper end, the cylindrical blast valve member **40** surrounds a projecting cylindrical support **41** upon which the valve member **40** is smoothly slidable. The support **41** is fixed to the casting **33** by suitable means (not shown). A suitable compression spring (not shown) positioned between the movable valve member **40** and the lower end of support **41** tends to hold the valve member **40** in its closed position against the valve seat **34**.

To protect support **41** and the upper end of valve member **40** from the harmful effects of arcing, a protective metallic tube **43** is positioned about these parts and is suitably secured to support **41**. Secured to the outer surface of this tube is a downstream probe or electrode **45**, preferably of a refractory metal, which projects radially from tube **43** and transversely into the path of the gas blast flowing through passageway **36**. As will soon appear more clearly, the downstream terminal of the arc is transferred to this electrode **45** during an interrupting operation and, after such transfer, occupies an instantaneous position generally corresponding to that shown at **46**. The downstream electrode is preferably constructed as shown and claimed in Patent No. 2,897,324-Schneider, assigned to the assignee of the present invention, so that it has a non-streamlined upstream surface **48** that coacts with the gas blast to form a stagnation region upstream from the surface **48**. The terminal of an arc such as **46** reaching the electrode **45** is captured within the stagnation region and thus prevented from being driven further downstream by the gas blast.

For controlling the operation of movable blast valve **40** and movable contact **16**, a combined operating mechanism **50** is provided. This mechanism **50** is preferably constructed in the manner disclosed and claimed in the aforementioned Beatty Patent 2,783,338, and its details form no part of the present invention. Generally speaking, this mechanism **50** comprises a blast valve-controlling piston **51** and a contact-controlling piston **52** mounted within the cylinder **32**. Blast valve-controlling piston **51** is coupled to movable blast valve member **40** through a piston rod **54** suitably clamped to valve member **40**. The contact-controlling piston **52**, on the other hand, is connected to the movable contact **16** through a piston rod **58** and a cross head **59** secured to the piston rod. A link **60** pivotally joined to the cross head **59** at **61** and to the movable contact **16** at **62** interconnects cross head **59** and movable contact **16**. When blast valve-controlling piston **51** is driven upwardly, it acts to open blast valve member **40**, and, simultaneously, to drive contact-controlling piston **52** upwardly to produce opening movement of the movable contact member **16**.

Opening movement of contact member **16** first establishes an arc between the ends of the contacts **14** and **16**. Shortly thereafter, however, the blast of gas which has been flowing through the orifice opening **37**, as indicated by the dotted-line arrows B, forces the upstream terminal of the arc on to an upstream arcing electrode **70**, which is electrically connected to the stationary contact **14**. As opening motion of movable contact **16** continues, the gas blast forces the downstream terminal of the arc to transfer from the movable contact **16** to orifice structure **39**, which is electrically connected to the movable contact **16**. The gas blast then impels the downstream terminal of the arc through the orifice opening **37** and nozzle **38** onto the upper end of the protective metallic tube **43**. From there, the gas blast drives the downstream arc terminal downwardly and into the previously-described stagnation region adjacent the upstream surface **48** of the electrode **45**. The arc then occupies, for a brief instant, the position generally shown at **46**. When the arc is in this position, the arc column extends through the orifice opening **37** and is subjected to the cooling and deionizing effect of the axial blast.

After completion of the interrupting operation, the blast valve **40** is returned to its closed position of FIG. 1 by the operating mechanism **50** while the contacts **14**, **16** remain open.

It is generally understood that the ability of the circuit breaker to prevent the arc from reigniting at a current zero depends upon the rate at which dielectric strength is recovered across the arcing region when arcing ceases at current zero. The faster the dielectric recovery rate, the lower the chances for reignition and thus the better the chances for successful interruption at this point.

It has been recognized that improvements in this dielectric recovery rate can be made by rotating the upstream terminal of the arc about a central point on the downstream face of the upstream electrode. For effecting such rotation, I use magnetic means similar to that shown and claimed in the aforesaid Beatty Patent 3,274,365. In this arrangement the magnetic force for rotating the arc is derived from a coil **80** electrically in series with electrode **70** and behind the downstream face of electrode **70**. This coil **80** encircles a conductive stud **82** which carries current to and from the upstream electrode. The left hand end of coil **80** is electrically connected to the free end of stud **82**, and the right hand end of coil **80** is electrically connected to electrode **70** at the rear end of the electrode. Suitable insulation **72** assures that current flowing through electrode **70** will not bypass the coil or any of its turns.

Electrode **70** is a cup-shaped member having an end cap **84** at its rear end to which the right hand end of coil **80** is connected. Electrode **70** comprises a tubular wall portion **85** surrounding coil **80** and a convex forward portion, or base portion, **86** of refractory metal brazed to the tubular wall portion. Forward portion **86** has a centrally-disposed opening **87** located therein. This opening is lined by an annulus **88** of insulating material defining a passageway **89** therethrough.

When the upstream arc terminal is transferred from the stationary contact **14** to the electrode **70**, as was described hereinabove, it is forced by the main axial blast enveloping the electrode **70** to move toward the forward end of the electrode. Current is then flowing through coil **80** since coil **80** is then connected in series with the arc. This current through coil **80** produces a radial magnetic field that has its longitudinal center line extending through central passage **89** toward the downstream electrode. The approximate configuration of this magnetic field is generally illustrated by the dotted lines of force M in FIG. 2, which extend radially outward from the central longitudinal axis in the region downstream of electrode **70**. This radial magnetic field reacts in a known manner with the local field surrounding the arc to produce a circumferentially-acting force that rotates the upstream arc terminal about the central passage **89**.

It should be noted that in the central region of the upstream electrode **70**, the magnetic field resulting from current through coil **80** has virtually no radial component. The direction of the field is almost entirely axial in the central region, and thus the magnetic field has little or no ability to rotate an arc that might have its terminal located in this region. For this reason, it has been customary to provide some means for excluding the arc from the central region. In the disclosed embodiment, there is provided central opening **87** and annular member **88** of insulating material lining the central opening for excluding the arc from the central region.

I have found that a serious limitation which prevents full exploitation of the beneficial effects of magnetic rotation is imposed by the aerodynamic forces which tend to center the arc column along the longitudinal axis of the main orifice opening **37**. Although the arc terminal can be held off center at the upstream electrode by the inclusion of means such as **87**, **88**, the aerodynamic forces of the axial blast tend to cause the arc column to bend almost immediately into a position along the longitudinal axis of symmetry where the magnetic field is ineffective. This relationship is illustrated in FIG. 3, which shows the electrode of the aforesaid Beatty Patent 3,274,365, being enveloped by an axial blast of gas. The primary flow paths followed by the gas blast as it streams past the upstream electrode are designated B as shown in FIG. 3, the innermost of these paths B follows the external contour of the electrode rather closely about the outer periphery of the electrode, separating slightly from the forward surface of the electrode, but converging only a short distance downstream from the forward surface. The aerodynamic effect of this blast is to cause the arc column **46***b* to bend almost immediately into the illustrated position of FIG. 3 along the central axis of the upstream electrode. Since the magnetic field has little or no radial component along this central axis, it is not capable of rotating the main portion of the arc terminal. It can rotate only the terminal region immediately adjacent the upstream electrode.

To provide for rotation of the arc column along a major portion of its length, instead of merely in the localized region adjacent the upstream electrode, I inject major portion of its length, instead of merely in the localized region adjacent the upstream electrode, I inject a high velocity jet **100** of gas into the main gas blast this jet **100** is directed through passage **89** into orifice opening **37** along the central longitudinal axis of the radial magnetic field, with its central axis substantially coinciding with the central longitudinal axis of the magnetic field. Jet **100** is derived from a reservoir **102** in stud **135** that is at a much higher pressure than the pressure of the gas in tank **12** following paths B. In a preferred form of the invention, the reservoir **102** from which the jet **100** is derived is at a pressure of 1500 p.s.i. as compared to a normal pressure inside the tank **12** of 500 p.s.i. This high pressure gas is supplied to reservoir **102** through a suitable supply line **103**. Because of the much higher pressure of its source, high pressure jet **100** has a velocity that is much higher than the velocity of the gas that is following paths B. A similar high velocity jet is employed, but for a different purpose, in the circuit breaker of my U.S. Patent 3,270,173.

The high velocity of jet **100** and the converging blast B surrounding jet **100** act together to maintain the jet constricted and well defined, preventing its diffusion along the major portion of its length, extending from the upstream electrode well downstream of the orifice opening **37**. The high velocity of the jet and the coolness of its core prevent the arc from penetrating the jet, thereby maintaining it spaced a substantial distance from the center line of the jet. Since the jet centerline coincides with the longitudinal axis of the radial magnetic field, the arc column as indicated at **46** in FIG. 2 is correspondingly maintained spaced a substantial distance from the

longitudinal axis of the radial magnetic field. The arc column at **46** is therefore traversed by the transversely-extending lines of force M which are effective to cause its rotation along substantially its entire length.

By rotating the arc column relative to jet **100**, higher shear velocities are created in the immediate region of the arc column, thereby enhancing turbulent mixing in this region and facilitating cooling of the arc all along its length. For very high currents, the radial magnetic field appears to force the arc column into the form of a cylindrical sheet surrounding the cooled jet and rotating about it, as indicated in FIG. 2. This sheet form exposes a larger surface of the arc to the intense turbulent mixing occurring at the jet boundary, thereby accelerating the cooling process. This accelerated cooling improves the rate of dielectric recovery at current zero under high current interrupting conditions.

In the prior art structure shown in FIG. 3, there is a passageway **89** in the downstream face of the electrode through which gas can flow via flow paths C. This gas flow, however, is radically different from the high velocity jet **100** employed in the electrode of my invention. In this respect, note that the gas flowing through passage **89** is derived via path C and openings **91** from the same source as the main axial blast. As a result, this gas flow through passage **89** is not a jet having a velocity higher than the surrounding main blast B. As a matter of fact, the velocity of the flow through the central passage **89** is even less than that of the surrounding main blast.

In view of its relatively low velocity, this gas flow through **89** in FIG. 3 is ineffective to overcome the centering effect of the main blast, and the arc configuration remains as shown in FIG. 3, even though there is some gas flow through **89**. This is in marked contrast to my electrode where a jet of much higher velocity than the surrounding main blast is derived from an ultra high pressure source **102** having a much higher pressure than the pressure in tank **12**. My high velocity jet **100** overcomes the centering effect of the main axial blast and prevents formation of the radial-inward bend illustrated in FIG. 3.

For initiating and terminating the jet **100**, an auxiliary valve **105** is provided in the flow passage leading from reservoir **102** to the opening **89**. This flow passage extends through the interior of hollow stud **82** and through a wall **106** of the reservoir. The wall **106** has an opening therein forming a valve seat in which a movable valve member **107** is normally located. For operating the movable valve member, a piston **109** connected to the valve member through an operating rod **112** is provided. Piston **109** is slidably mounted in cylinder **110**, which communicates with high pressure reservoir **102** via a passage **114** at the lower side of piston **109**. The upper side of piston **109** communicates with high pressure reservoir **102** through lines **123** and **122** and a pilot valve **120** shown in the open position. Since the effective upper surface of the piston is larger than the effective lower surface, there is a net force from the high pressure gas biasing piston **109** and valve member **107** into their illustrated closed positions so long as equal pressures prevail on opposite sides of piston **109**. A light compression spring **115** above piston **109** holds valve member **105** closed when no pressurized gas is present, thereby permitting initial filling of reservoir **102**.

When pilot valve **120** is operated from its open position shown to its venting position, it establishes communication between lines **123** and **124**, thereby venting the space at the upper side of piston **109** to a low pressure region. This allows the high pressure gas on the lower side of the piston to drive the piston upwardly into its dotted line position, thereby opening valve **107**. After such a valve-opening operation, closing of the valve member **107** is effected by returning the pilot valve **120** to its illustrated position. This reestablishes communication between lines **122** and **123**, causing a pressure build-

up above piston **109** that returns the piston and valve member **107** to their closed positions shown. The means for controlling the pilot valve is shown schematically at **130** and will soon be described in greater detail. It is to be understood that the valve-operator **109, 110, 120** has also been shown schematically in order to facilitate an understanding of the invention.

Although jet **100** substantially improves the dielectric recovery rate for high currents, such as fault currents, it has been found through extensive study and tests that it detracts from the ability of the circuit breaker to switch capacitive currents, which typically are only several hundred amperes or less. As explained in U.S. Patent 2,391,672-Boehne et al., assigned to the assignee of the present invention, interruption of such a current at current zero is followed by a relatively slow voltage build-up to a value approaching twice normal crest voltage. For some reason, not fully understood, the jet **100** appears to detract from the circuit breaker's ability to withstand this voltage, even though it substantially increases its ability to handle the much steeper voltage rises following current zero during the interruption of an inductive circuit. To improve the ability of the circuit breaker to handle capacitive currents, I control the jet-initiating valve **105** in such a manner that it opens for relatively high currents, remaining closed for low currents. For example, in a typical circuit breaker, I open the jet-initiating valve only when the instantaneous current exceeds about 10,000 amperes. Capacitive currents are typically only as high as several hundred amperes. So it will be evident that no jet is established during capacitive switching operations. The operating current level for the valve **105** is established well above the continuous current rating of the circuit breaker so that the highest normal current will not cause the jet-initiating valve **105** to open.

For operating the pilot valve **120** in response to current magnitude, I provide a magnetizable core **132** around the conductive stud **135**. Referring to FIG. 4, core **132** has a gap therein and an armature **134** is located near the gap. When the current through stud **135** exceeds a predetermined value, the flux through core **132** becomes high enough to pull the armature **134** downwardly into the gap, thereby operating a linkage **137, 140** that actuates pilot valve **120**. Referring to FIGS. 2 and 4, this linkage **137, 140** is shown schematically as comprising a rod **137** connected to armature **134** and suitably guided for vertical movement in brackets **138**. The linkage further comprises an operating lever **140** connected between the upper end of rod **137** and the rotary element of the pilot valve. A reset spring **142** normally holds the parts in the position of FIGS. 2 and 4. When the current through stud **135** exceeds a predetermined value, a sufficient downward magnetic force is developed on armature **134** to move it downwardly against the bias of spring **142**, thereby pivoting operating lever **140** clockwise about the axis of the rotary pilot valve element, thus shifting the rotary pilot valve element into its venting position, to effect opening of the jet-initiating valve **105**.

In the embodiment of FIG. 1, no effort is made to develop any magnetic force at the downstream electrode to rotate the downstream terminal of the arc. The downstream probe **45** is, however, made large enough to provide a stagnation zone adjacent its upstream surface of sufficient size to permit any rotational movement of the downstream arc terminal which accompanies rotational movement of the arc column, as described hereinabove. The jet **100** is preferably aimed directly at the stagnation zone on the downstream electrode.

In the embodiment of FIG. 5, I develop an arc-rotating magnetic force in the immediate vicinity of the downstream electrode to facilitate rotation of the downstream terminal and the adjacent portion of the arc terminal. Referring to FIG. 5, the downstream terminal comprises a cup-shaped member **150** having a base **152** and an annular flange **154** at the base periphery extending from the base toward the upstream electrode. The cup-shaped configuration of the downstream electrode results in the formation of a stagnation zone inside the cup in which the downstream terminal of the arc is held captive. A series of radially extending holes **155** are provided in flanges **152** around the periphery of the electrode to provide for scavenging of the upstream surface of downstream electrode **150**. A relatively large number of these holes are distributed uniformly about the entire periphery to provide for a balanced radially-outward flow that helps to discourage the arc from sticking in any one circumferentially-localized spot on the base **152**.

The magnetic force for rotating the arc is derived from a suitable coil **160** locating behind the cup-shaped electrode **150** and connected electrically in series therewith. Current flowing through this coil **160** develops a radial magnetic field **162** that applies a circumferentially acting force to the arc.

Centrally of the cup-shaped electrode there is an insulating insert **164** that excludes the arc terminal from this region. The jet **100** is aimed at this insert **164**, and the insert acts to prevent the arc column from finding a central position near the downstream electrode where the magnetic field would not be effective to produce arc rotation due to the actions of a radial component.

Although I have shown the annular flange **154** as being formed of metal, it is to be understood that this flange could also be formed of insulating material or covered with insulating material. The base **152** of such an electrode must, of course, be of metal to provide a suitable foot point for the downstream arc terminal.

In the embodiment of FIG. 5, the upstream electrode is preferably constructed in the same manner as the upstream electrode of FIG. 1. The main orifice **39, 37** is also the same as in FIG. 1.

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from the invention in its broader aspects; and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. An axial-blast, gas-blast circuit breaker comprising:
   (a) an upstream electrode and a downstream electrode,
   (b) an orifice having an opening positioned between said electrodes,
   (c) means for establishing an arc between said electrodes that extends through said orifice opening,
   (d) means operative when said arc is established for causing an axial blast of gas to flow through said orifice opening via paths extending along the external surface of said upstream electrode and generally axially of said arc adjacent said upstream electrode,
   (e) said upstream electrode having a downstream surface facing said orifice opening,
   (f) means for developing an arc-rotating radial magnetic field that has its central longitudinal axis extending generally parallel to the column of said arc and has lines of force extending radially outward from said central longitudinal axis across said arc column at locations downstream from the downstream surface,
   (g) and means for maintaining a major portion of the column of said arc radially-spaced from the central longitudinal axis of said radial magnetic field, comprising:
      (i) a passageway leading through said downstream surface generally along the central longitudinal axis of said radial magnetic field and directed toward said orifice opening,

(ii) means operative when said blast is flowing for directing a jet of gas through said passageway and said orifice opening that is generally surrounded by said blast, and

(iii) means for causing said jet to have a velocity as it enters the orifice opening that is substantially higher than the velocity of said blast surrounding the jet.

2. The gas blast circuit breaker of claim 1 in combination with:

(a) valve means operable to initiate said jet,

(b) current-responsive means for operating said valve means in response to currents exceeding a predetermined value,

(c) and means for maintaining said valve means in a non-operated condition during the interruption of currents less than said predetermined value,

(d) said predetermined value being sufficiently high that said jet is not established during capacitance switching operations.

3. The gas blast circuit breaker of claim 1 in combination with electroresponsive valve means for causing said jet to be established only during the interruption of currents having a higher value than the currents accompanying capacitance switching operations.

4. An axial-blast, gas-blast circuit breaker comprising:

(a) an upstream electrode and a downstream electrode,

(b) an orifice having an opening positioned between said electrodes,

(c) means for establishing an arc between said electrodes that extends through said orifice opening,

(d) means operative when said arc is established for causing an axial blast of gas to flow through said orifice opening via paths extending along the external surface of said upstream electrode and generally axially of said arc adjacent said upstream electrode,

(e) said upstream electrode having a downstream surface facing said orifice opening,

(f) a passage leading through said downstream surface generally along the central longitudinal axis of said radial magnetic field and directed toward said orifice opening,

(g) means operative when said blast is flowing for directing a jet of gas through said passage and said orifice opening that is generally surrounded by said axial blast,

(h) means for causing said jet to have a velocity as it enters the orifice opening that is substantially higher than the velocity of said blast surrounding the jet,

(i) valve means operable to initiate said jet,

(j) current-responsive means for operating said valve means in response to current exceeding a predetermined value,

(k) and means for maintaining said valve means in a non-operated condition during the interruption of currents less than said predetermined value,

(l) said predetermined value being sufficiently high that said jet is not established during capacitance switching operations.

5. The circuit breaker of claim 1 in which:

(a) said downstream electrode comprises a cup-shaped structure having a base facing said upstream electrode and a flange extending about the periphery of said base and projecting toward said upstream electrode, and

(b) arc-rotating means is provided adjacent said downstream electrode for developing a radial field that causes the downstream arc terminal to rotate about the central region of said base via a path located radially inwardly of said flange.

6. The circuit interrupter of claim 5 in which a series of generally-radially extending holes is provided in said flange at circumferentially-spaced points around the periphery of said base to provide for scavenging of the upstream surface of said base with radially-outward flow at a plurality of circumferentially-spaced points.

7. The gas blast circuit breaker of claim 5 in which said jet impinges against said base in its central region.

8. The gas blast circuit interrupter of claim 1 in combination with additional arc-rotating means adjacent said downstream electrode for developing a radial magnetic field adjacent the downstream electrodes to assist in rotating the arc column.

References Cited

UNITED STATES PATENTS

3,270,173	8/1966	Barkan.	
3,274,365	9/1966	Beatty.	
3,315,056	4/1967	Furukawa	200—148
3,418,440	12/1968	Beatty et al.	200—147 X

ROBERT S. MACON, Primary Examiner

U.S. Cl. X.R.

200—147