Dec. 24, 1968 J. W. BEATTY ET AL 3,418,440

GAS-BLAST CIRCUIT BREAKER

Filed Sept. 14, 1965 3 Sheets-Sheet 1

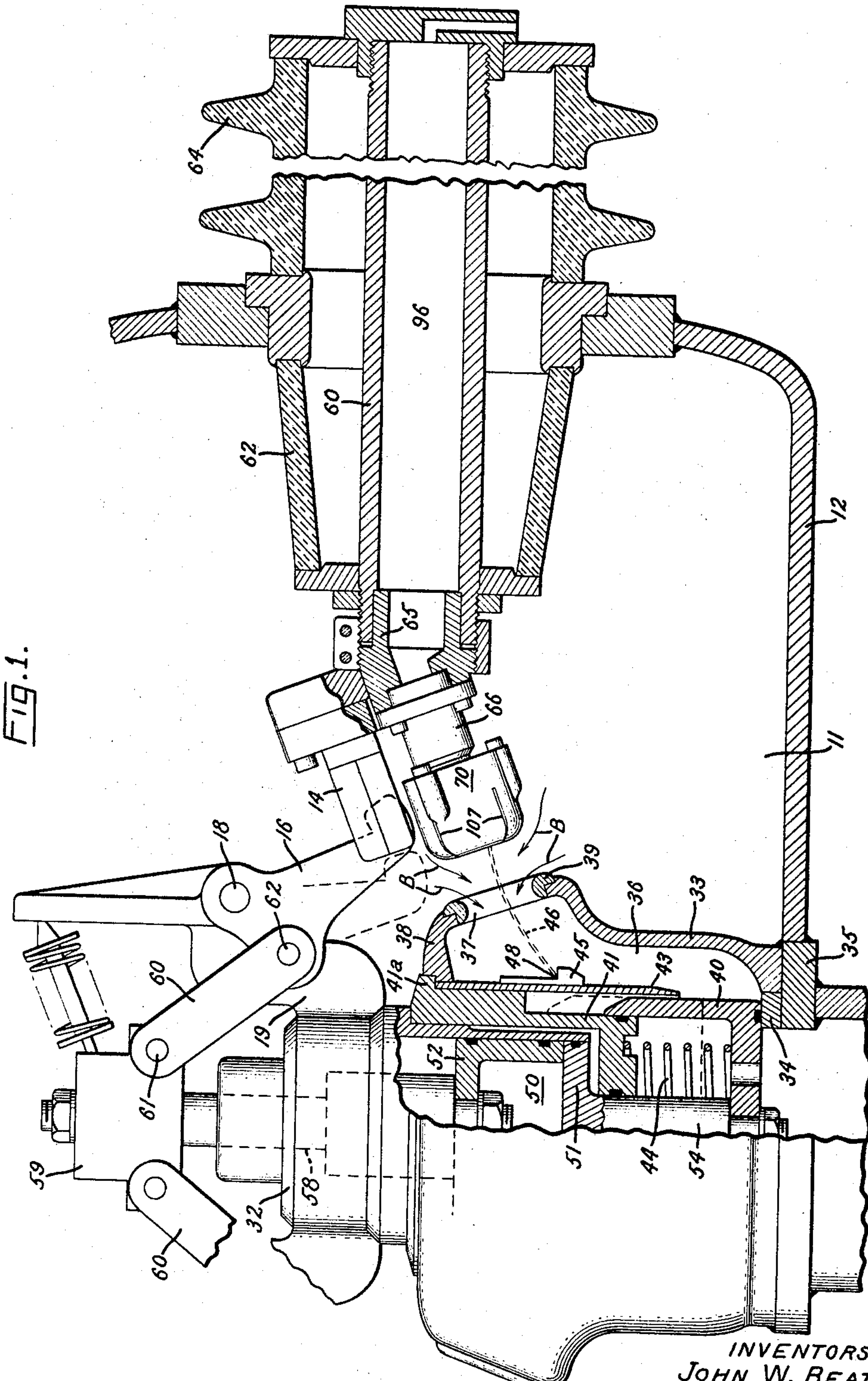

FIG. 1.

INVENTORS:
JOHN W. BEATTY,
GEORGE McNEIR,

BY William Freedman
ATTORNEY

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FIG. 2.

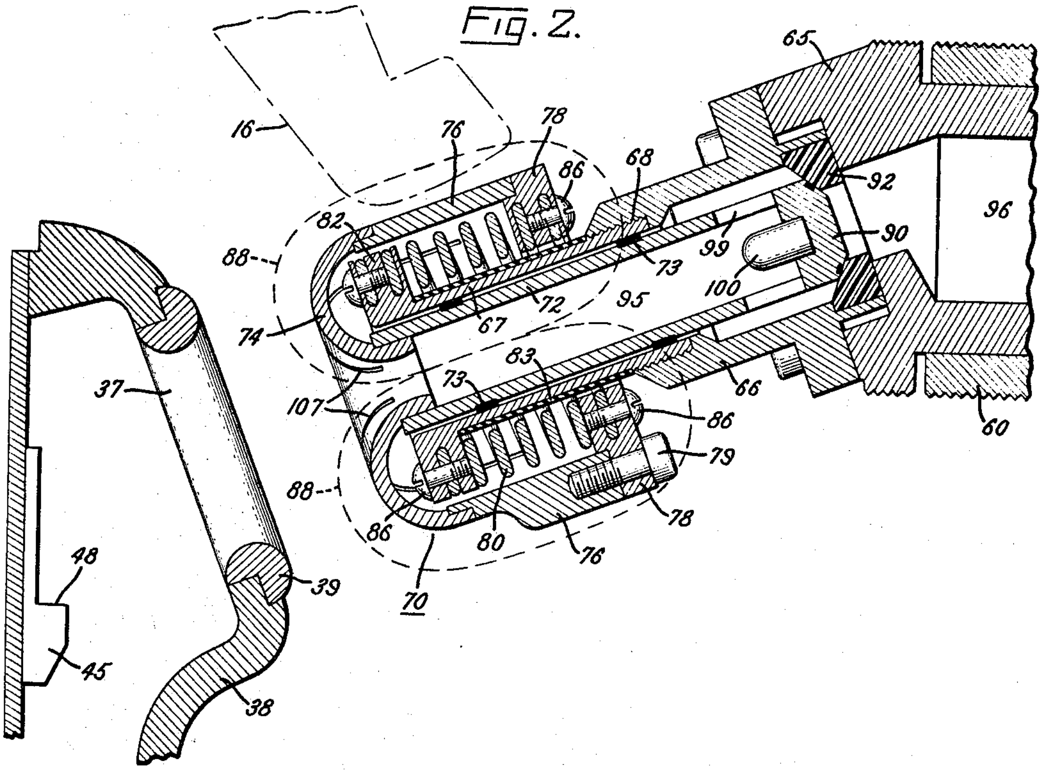
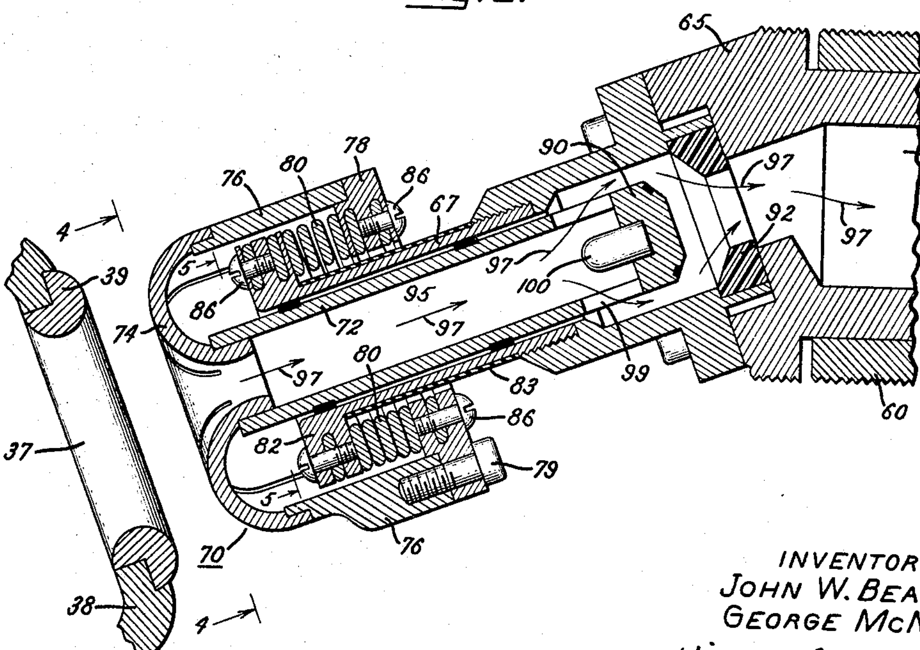


FIG. 3.



INVENTORS:
JOHN W. BEATTY,
GEORGE MCNEIR,

BY William Friedman

ATTORNEY

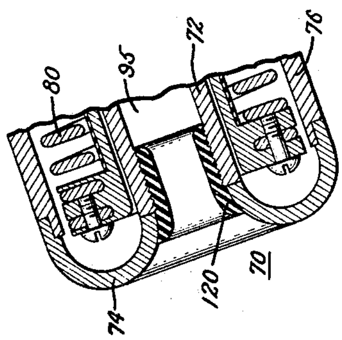


Fig. 7.

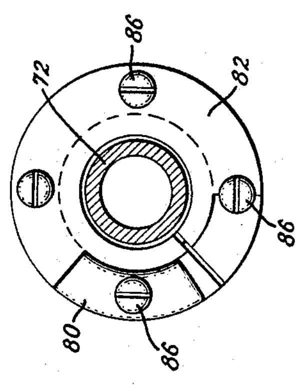


Fig. 5.

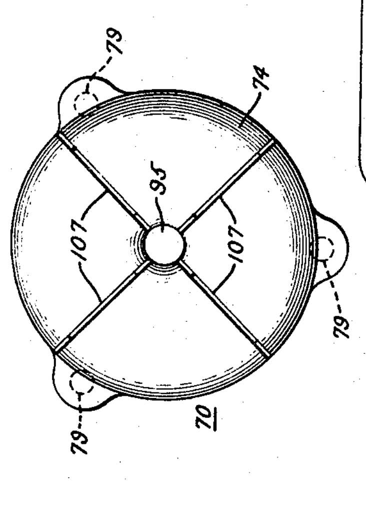


Fig. 4.

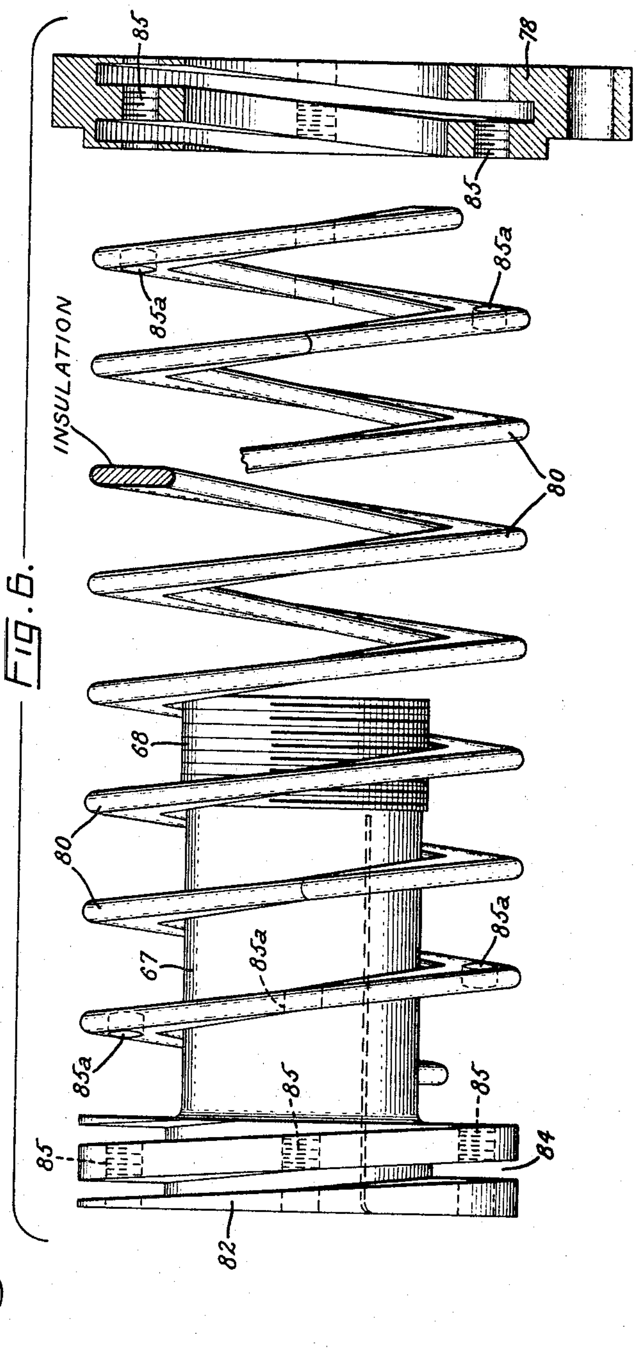


Fig. 6.

INVENTORS:
JOHN W. BEATTY,
GEORGE MCNEIR,

BY William Freedman
ATTORNEY

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GAS-BLAST CIRCUIT BREAKER

John W. Beatty, Newtown Square, and George McNeir, Lansdowne, Pa., assignors to General Electric Company, a corporation of New York

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10 Claims. (Cl. 200—148)

ABSTRACT OF THE DISCLOSURE

Gas-blast circuit breaker in which the electrodes of the breaker are normally spaced-apart by a relatively large amount to provide a high dielectric strength, but during high current interruptions the electrode spacing is reduced to provide for higher interrupting capacity than is available with the normal large electrode-spacing. Immediately after interruption, the normal large electrode-spacing is restored. The above reduction in electrode-spacing is produced by an electromagnet in series with the electrodes, which also produces a radial field for arc rotation and force for opening an auxiliary blast valve.

This invention relates to a gas-blast circuit breaker and, more particularly, relates to means for improving the interrupting ability of such a circuit breaker.

The usual gas-blast circuit breaker comprises means for establishing an electric arc across a gap between two electrodes and means for directing a high velocity 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 that builds up as soon as a current zero is reached, thus improving the interrupting ability of the circuit breaker.

For extra high voltage applications, the spacing between the electrodes of an open circuit breaker must be relatively great in order to meet the severe insulation requirements these high voltages impose. It may seem that it should not be a difficult matter to provide the relatively great inter-electrode spacing required; but when the required spacing has been provided, an impairment in current-interrupting ability has been noted. In other words, the inter-electrode spacing most favorable for interruption has been found to be substantially shorter than that required to withstand the extra high voltages.

An object of the present invention is to provide a new and improved gas-blast circuit breaker in which the relatively great inter-electrode spacing required for extra high voltage applications is provided without detracting from the ability that the breaker has to interrupt currents at shorter inter-electrode spacings.

In carrying out our invention in one form, we provide a pair of electrodes that are normally spaced-apart by the relatively large amount needed to meet extra high voltage

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insulating requirements. One of these electrodes is mounted for movement to and from the other electrode. Actuating means responsive to current through the movable electrode is provided for moving the movable electrode toward the other electrode when the current is relatively high. When the current falls below a predetermined level, the movable electrode is quickly returned to its normal position to reestablish the relatively large inter-electrode spacing originally present.

It has been found that the interrupting ability of a gas blast circuit breaker can be improved by rotating one of the terminals of the arc during the interrupting period. This can be done by providing a radial magnetic field that extends transversely of the arc.

Another object of our invention is to provide means capable of performing the dual function of (1) producing the desired magnetic field for arc rotation and (2) producing the force required for shortening the inter-electrode gap during high current interruptions.

A common type of gas-blast circuit breaker is the axial-blast type breaker. In such a breaker the blast of gas flows axially of the arc, first passing the one electrode which is normally referred to as the upstream electrode and then passing the other electrode, which is referred to as the downstream electrode. It has been found that the interrupting capacity of the axial-blast type breaker can be improved by providing an auxiliary blast passage in the upstream electrode, through which an auxiliary blast is directed during interruption.

Another object of our invention is to provide new and improved means for controlling the flow of gas through this auxiliary blast passage.

Still another object is to control this auxiliary blast with a valve actuated by force derived from the same means that is used for effecting the above-described control of the position of the movable electrode.

In carrying out these additional objects in accordance with one form of our invention, we provide an auxiliary blast passage leading through the upstream electrode. Flow through this passage is controlled by a normally-closed auxiliary blast valve. The normally-closed auxiliary blast valve is controlled by current responsive means which opens the auxiliary blast valve in response to current through the upstream electrode exceeding a predetermined value. In a preferred form of the invention, the movable valve element of the auxiliary blast valve is coupled to the previously-described movable electrode, and both the movable electrode and the auxiliary blast valve are operated by the current responsive valve-control means. When the current through the electrode exceeds a predetermined value, the current responsive valve-control means drives the movable electrode into its shorter-gap, preferred interrupting, position and also drives the movable valve element into a position that opens the auxiliary blast valve.

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

FIG. 1 is a view, partly in section, of a gas-blast circuit breaker embodying one form of our invention.

FIG. 2 is an enlarged sectional view of a portion of a circuit breaker of FIG. 1. The parts are shown in the positions they occupy when the circuit breaker is closed.

FIG. 3 illustrates the parts of FIG. 2 during a high current interruption.

FIG. 4 is a sectional view taken along the line 4—4 of FIG. 3.

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

FIG. 6 is an enlarged exploded view of a portion of FIG. 2.

FIG. 7 is a sectional view similar to that of FIG. 2 but showing a modified form of the invention.

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 to 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 my above-mentioned 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**. When the movable contact **16** is driven clockwise about the 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.

The 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**. The cylinder **32** at its lower end is suitably supported from a generally cylindrical casting **33**. The 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, the cylindrical casting **33** contains a normally-closed exhaust passage **36** leading from the interrupting chamber **11** to the surrounding atmosphere. The casting **33** at its upper end is provided with a tubular nozzle-type electrode **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 the tubular nozzle **38** and the exhaust passage **36** is controlled by means of a cylindrically-shaped reciprocable blast valve member **40** located at the outer, or lower, end of the exhaust passage **36**. This blast valve member **40** normally occupies a solid-line, closed position wherein its lower end face sealingly abuts against a stationary valve seat **34** carried by the exhaust casting **33**.

During a circuit-interrupting operation, the 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 the valve member **40** allows pressurized gas in the chamber **11** to flow at high speed through the orifice opening **37** and nozzle **38** and out the exhaust passageway **36** past the valve member **40** to atmosphere, as indicated by the 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 valve member **40** surrounds a projecting tubular support **41** upon which the valve member **40** is smoothly slidable. The tubular support **41** is fixed to the casting **33**, preferably, by means of bolts (not shown) clamping the flange **41*a*** to the top of casting **33**. A compression spring **44** 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 the support **41** and the upper end of the valve member **40** from the harmful effects of arcing, a protective metallic tube **43** is positioned about these parts and is suitably secured to the 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 the tube **43** and transversely into the path of the gas blast flowing through the 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 a position generally corresponding to that shown at **46**. The downstream electrode is preferably constructed as shown and claimed in Patent No. 2,897,324 to 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 the movable blast valve **40** and movable contact **16**, a combined operating mechanism <u>50</u> is provided. This mechanism <u>50</u> 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 <u>50</u> comprises a valve-controlling piston **51** and a contact-controlling piston **52** mounted within the cylinder **32**. The valve-controlling piston **51** is coupled to the movable valve member **40** through a piston rod **54** suitably clamped to the 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 the cross head **59** and the movable contact **16**. When the valve-controlling piston **51** is driven upwardly, it acts to open the valve member **40**, and, simultaneously, to drive the contact-controlling piston **52** upwardly to produce opening movement of the movable contact member **16**.

Opening movement of the 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 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 them ovable contact **16** continues, the gas blast forces the downstream terminal of the arc to transfer from them ovable 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** on to 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 the position generally shown at **46** with its upstream terminal on the upstream electrode **70** and its downstream terminal on the downstream electrode **45**. When the arc is in this position, the arc column extends through the orifice opening **37** and is subjected in the orifice region to an intense high velocity blast that extends axially of the arc. This axial blast is effective to cool and deionize the arc and scavenge the arcing region of arcing products, thus preventing reignition thereof at an early current zero.

After interruption is completed, the blast valve 40 is returned in a downward direction to its solid line position of FIG. 1, thereby terminating the arc-extinguishing blast. This blast valve-closing is effected by supplying pressurized air to the space between the two pistons 52 and 61. This pressurized air holds the movable contact 16 in its open position when the blast valve has closed.

It will be noted that the stationary contact 14 and its associated upstream electrode 70 are supported on a hollow conductive stud 60. This stud 60 also serves to carry current to and from the stationary contact 14 and the upstream electrode 70. The hollow stud 60 extends through the wall of the casing 12 and is supported on the casing 12 by tubular porcelain sleeves 62 and 64 surrounding the stud. These porcelain sleeves 62 and 64 together with the stud 60 constitute a terminal bushing of a generally conventional design.

For increasing the amount of current that the circuit breaker can interrupt, a number of important new features have been incorporated into the upsteam electrode 70. The manner in which these features contribute to increased interrupting capacity will soon be described, but first a description will be presented of the structure of these features.

For supporting the upstream electrode 70 on the stud 60, we provide a tubular adapter 65 that is suitably attached to the stud 60. Bolted to the adapter 65 is a tubular valve casing 66, to which is secured a tubular guide member 67 (FIG. 2). These tubular parts 66 and 67 are joined together by a suitable threaded joint 68. Attached to the upstream electrode 70 is a centrally located tubular valve stem 72 that is slidably supported within the guide member 67. Suitable slide bearings 73 of insulating material are provided between the stationary guide member 67 and the valve stem 72 to permit longitudinal movement of the stem within the guide member 67 under certain conditions soon to be described.

The upstream electrode 70 is a cup-shaped member that comprises a semi-toroidal forward portion 74 and a tubular wall portion 76 joined to the semi-toroidal forward portion at its outer periphery. At the rear end of the tubular wall portion 76, an annular radially-inwardly projecting flange 78 is provided. This flange 78 is detachably connected to the tubular wall portion, as by screws 79.

For carrying current between the tubular supporting structure 66, 67 and the upstream electrode 70, we provide a helically wound spring 80 encircling the tubular guide member 67. This spring 80 is electrically and mechanically connected at its forward end to a flange 82 projecting radially outward from the guide member 67 and integral therewith. The spring 80 is electrically and mechanically connected at its rear end to the inwardly projecting flange 78 on the electrode 70. This helically wound spring 80 is preferably made of a copper-beryllium alloy, and all of its turns except those at its extreme ends are coated with a thin layer of electrical insulation that prevents current through the spring from bypassing the turns. An insulating sleeve 83 encircling the guide member also aids in preventing any current from bypassing the turns of spring 80. Thus, current flowing between the tubular guide member 67 and the upstream electrode follows the helical path defined by the turns of spring 80.

Current flowing through the helical path defined by the turns of spring 80 develops a radial magnetic field, as indicated by the lines of magnetic force 88 (FIG. 2). This radial magnetic field is used for rotating the upstream terminal of the arc in a manner that will soon be described.

For providing a mechanically strong connection between the spring 80 and the flange 82, the flange 82 is provided with a helical groove 84 into which the helical

spring 80 is threaded. This connection is best shown in FIG. 6. Four tapped holes are provided in the flange 82 at angularly-spaced points, and these holes register with holes 85*a* in the spring 80. Screws 86 extend through the holes in the spring and are threaded into the tapped holes 85 in the flange. These screws 86 clamp the walls of the groove in high pressure engagement with the adjacent surfaces of the spring 80 and also prevent the spring from unscrewing from the groove 84. A similar connection is provided between the rear end of the spring 80 and the flange 78 on the electrode 70.

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 air blast B enveloping the electrode 70 to move toward the forward face of the electrode. No current flows through the spring 80 until the arc is transferred to the electrode 70, but after this transfer has occurred, current flows through the spring 80 and produces the magnetic field 88 referred to hereinabove. When the upstream arc terminal moves into the region adjacent the forward face of the electrode, the magnetic field 88 extends radially with respect to the axially-extending arc and is thus able to produce rotation of the upstream arc terminal about the central portion of the electrode.

For accentuating the forces urging the upstream arc terminal toward the forward face of the electrode 70, slots 107 are provided in the upstream electrode. These slots extend radially outward from the central region of the electrode and then axially of the electrode in the tubular wall portion 76. These slots 107 force most of the current flowing through the electrode to an arc terminal thereon to follow a path that approaches the arc solely from the back of the electrode. Current is blocked from following circumferentially-extending paths approaching the arc. By forcing most of the current to follow a path that approaches the arc from the back of the electrode, a more definite loop bowing toward the front face of the electrode is defined. This results in a greater magnetic force urging the arc toward the forward face of the electrode, thus accelerating movement of the upstream terminal to the forward face of the electrode.

Another function served by the coiled spring 80 is to provide a force on the upstream electrode 70 urging it to the right into its position of FIG. 2. In this position, a movable valve member 90 attached to the valve stem 72 abuts against a stationary annular valve seat 92, thus blocking further movement of the upstream electrode 70 to the right.

There is an auxiliary blast passage leading through the upstream electrode 70 is the hollow stud 60 to atmosphere. The portion of this auxiliary blast passage that extends through the electrode 70 is designated 95 and the portion extending through the stud 60 is designated 96. The auxiliary blast passage is normally closed by means of the normally-closed auxiliary blast valve 90, 92. But under high current conditions, as will soon be described, the movable auxiliary blast valve member 90 is moved to the left to open the auxiliary blast valve 90, 92, as shown in FIG. 3. This permits high pressure air to flow through the auxiliary blast passage 95, 96 via the then-open auxiliary blast valve 90, 92. The path of the auxiliary blast is indicated by the arrows 97 in FIG. 3, where the auxiliary blast can be seen passing through openings 99 and the stem 72 and then through the central opening annular valve seat 92.

The force for producing the above-described opening of the auxiliary blast valve 90, 92 is derived from current through the coiled spring 80. In a well-known manner, current flowing through the spring 80 will develop magnetic force that tends to draw together the turns of the spring. This action is opposed by the high pressure air in casing 12 acting to the right on the movable valve member 90 and, to a lesser extent, by the resilience of the spring 80. But when the current exceeds a predetermined value, sufficient magnetic force is developed to overcome this opposition and move the turns of the turns of the spring toward each. This forces the flange **78** and the upstream electrode **70** to the left from their position on FIG. 2 to that of FIG. 3. This leftward motion is transmitted through the valve stem **72** to effect opening of the movable valve member **90**.

The distance that the upstream electrode moves to the left can be controlled by a suitable stop. In the illustrated embodiment, we rely upon the spring **80** itself to provide this stop. When the turns of the spring engage each other, as shown in FIG. 3, leftward motion of the upstream electrode **70** is terminated.

The spring **80** can be designed so that the electromagnetic forces effect the above-described leftward motion of the electrode at any desired current level, assuming a given pressure in the tank **12**. In a preferred embodiment of the invention, we design the spring **80** so that the electromagnetic forces produce this leftward motion of the electrode when the current through the spring **80** is between 15,000 and 20,000 amperes, peak, assuming normal pressure of 800 p.s.i. is present in the tank.

When the current drops below this value, as when the arc is extinguished, the above-described opposing forces overcome the magnetic force between the turns of the spring **80** and thus return the movable valve member **90** to its closed position of FIG. 2.

If the circuit breaker is called upon to interrupt a current of a moderate or relatively low value, i.e., below 15,000 amperes peak, the current through the coiled spring **80** is insufficient to move the upstream electrodes out of its normal position of FIG. 1. It is thus insufficient to open the auxiliary blast valve **90, 92**. During such interruptions, the movable blast valve **40** opens and produces the main blast of air B that moves the arc into the position of FIG. 1, but there is no auxiliary blast through the auxiliary blast passage **95, 96**. There is, however, a radial magnetic field such as shown at **88** that acts to magnetically drive the upstream terminal of the arc **46** in a circular path about the central region of the electrode **70**. This radial-magnetic field **88** is produced by current flowing through coil **80**, as was previously described.

If the circuit breaker is called upon to interrupt a high current, the main blast B again moves the arc into the position illustrated in FIG. 1. This results in the high current flowing through the coil **80** developing a sufficient magnetic attraction between the turns of the coil spring **80** to drive the electrode **70** leftward into its position of FIG. 3. This leftward motion reduces the distance between the upstream electrode **70** and the orifice **39** and also opens the auxiliary blast valve **90, 92**.

The shorter spacing between the upstream electrode **70** and the orifice member **39** improves the interrupting ability of the circuit breaker, enabling it to interrupt appreciably higher currents than it could with the relatively long original gap length. We attribute the increased interrupting capacity, in part, to the higher velocity of the air in the region between the electrode **70** and the orifice member **39** when the spacing between these parts is reduced. Some of the increased interrupting capacity also appears to be attributable to the fact that the shorter gap between the electrode **70** and the orifice member **39** causes less arc energy to be released upstream of the orifice.

As soon as the arc is extinguished, no further current flows through the coiled spring **80** and the magnetic attraction between the turns of the spring will drop sharply. This allows the upstream electrode **70** to be quickly returned to its normal position of FIG. 2 by the air pressure in the tank **12** acting on the electrode **70** and the movable valve member **90**. This rapid reestablishment of the initial relatively great gap length serves the highly desirable purpose of increasing the dielectric strength across the gap immediately after circuit interruption is completed, thus reducing the chances that this gap will

be sparked over by any high voltage transients occurring during or after this crucial period.

When the upstream electrode **70** moved to the left, as above described, it also opened the auxiliary blast valve **90, 92** since the movable valve member **90** is mechanically connected to the electrode **70** through the valve stem **72**. Opening of the auxiliary blast valve caused an auxiliary blast to flow through the blast passage **95** in the upstream electrode, as was explained hereinabove. This auxiliary blast has been found to further increase the interrupting capacity of the circuit breaker. This increase in interrupting capacity appears to be attributable to improved scavenging that occurs in the region of the upstream electrode. This scavenging action quickly removes arcing products from in front of the upstream electrode, replacing them with fresh gas of much greater dielectric strength.

In some cases, the auxiliary blast will drive the upstream terminal of the arc inside the auxiliary blast passage **95**. For receiving the arc terminal when it is driven into this position, an arcing probe **100** of a refractory material is provided. The arc terminal will attach to this probe **100**, and this will prevent damage to adjacent parts of the auxiliary blast valve.

In those cases in which the upstream arc terminal does enter the auxiliary blast passage **95** and attach to the probe **100**, the arc column will be generally parallel to the radial field **88**. Under these conditions, there will be no substantial arc-rotating force. But prior to entry of the arc into the passage **95** there will be an arc-rotating force that rotates the arc to reduce the quantity of arcing products generated. Also, under lower current interrupting conditions when no auxiliary blast is present, the upstream arc terminal does not enter the auxiliary blast passage **95**, and the radial magnetic field **88** is effective to produce arc rotation. This desirably serves to reduce arc erosion of the upstream electrode. This arc rotation also allows higher currents to be interrupted with the relatively long gap that is present between the upstream electrode **70** and and orifice member **39**.

The fact that the auxiliary blast valve **90, 92** is maintained closed for low and moderate currents is advantageous since it greatly reduces the number of times that the valve will be called upon to open and close. This is particularly so since a high current fault is ordinarily a very rare occurrence. This reduced frequency of operation reduces wear on the valve elements, thereby materially prolonging their life and improving the reliability of the auxiliary blast valve.

Although the above-described form of our invention includes an auxiliary blast valve, our invention in its broader aspects comprehends an arangement in which there is no auxiliary blast valve or auxiliary blast passage. In such an arrangement, the only blast is the main blast at B. The arc-rotating means and gap length control means are still present, however, to aid circuit interruption.

Our invention in its broader aspects also comprehends other current responsive means instead of coiled spring **80** for changing the electrode spacing during high current interruptions.

In the modified form of my invention shown in FIG. 7, the upstream arc terminal is normally prevented from entering the auxiliary blast passage **95**. In this connection, a tubular insert **120** of a suitable insulating material is included in the upstream electrode **70**. This insert **120** provides a thick coating of insulating material on the portion of the upstream electrode surrounding the mouth of auxiliary blast passage **95**, thus blocking the arc terminal from moving into the auxiliary blast passage. By maintaining the upstream arc terminal on the forward portion **74** of the upstream electrode, the arc is kept in a position where the magnetic field from coil **80** extends transversely of the arc and is able to produce effective arc-rotation about the longitudinal axis of passage 95. A preferred material for the insert 120 is polytetrafluoroethylene, sold under the trademark Teflon.

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

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

1. An electric circuit breaker of the gas-blast type comprising:
(a) a pair of spaced-apart electrodes between which an arc is established during circuit interruption,
(b) one of said electrodes being relatively movable with respect to the other of said electrodes,
(c) said one electrode having a normal position where it is spaced by a predetermined first amount from said other electrode,
(d) means responsive to arcing current flowing through said one electrode for moving said one electrode toward said other electrode when the arcing current through said one electrode exceeds a predetermined value,
(e) means for holding said one electrode in a position spaced from said other electrode by a predetermined second amount substantially smaller than said first amount during the passage of high currents through said one electrode and arc,
(f) means for directing a blast of gas through the space between said electrodes while said arc is present therebetween, whereby to aid in extinguishing said arc,
(g) and means responsive to a fall in said arcing current to a predetermined level for returning said one electrode to its normal position spaced by said predetermined first amount from said other electrode.

2. The circuit breaker of claim 1 in combination with arc-rotating means for developing a magnetic field extending transversely of said arc for rotating at least a portion of said arc during the circuit-interrupting operation.

3. The circuit breaker of claim 1 in which the means for moving said one electrode toward the other electrode comprises an electromagnet that is energized by arcing current and develops in response to energization a magnetic field extending transversely of said arc and capable of rotating said arc.

4. The circuit breaker of claim 1 in which:
(a) said one electrode is of a hollow construction and said means responsive to arcing current comprises a coil located within said hollow electrode,
(b) a conductive member is provided projecting into said hollow electrode from the back thereof for supporting said electrode and for carrying current to and from said electrode, and
(c) said coil encircles said conductive member and is connected at one end to said conductive member and at its opposite end to a portion of said one electrode.

5. The circuit breaker of claim 1 in which said means for moving said one electrode toward said other electrode comprises:
(a) a coil connected in series with said one electrode, said coil having turns that are normally spaced from each other and which move toward each other when traversed by high currents,
(b) and means for moving said one electrode toward said other electrode in response to motion of said turns toward each other.

6. The circuit breaker of claim 1 in combination with:
(a) a main blast passage adjacent said other electrode through which the gas blast of claim 1 is directed,
(b) an auxiliary blast passage extending through said one electrode,

(c) a normally-closed auxiliary blast valve for controlling flows through said auxiliary blast passage,
(d) means controlled by movement of said one electrode toward said other electrode for opening said auxiliary blast valve to produce an auxiliary blast through said auxiliary blast passage during high current interruptions,
(e) and means for closing said auxiliary blast valve in response to said return movement of said one electrode to its normal position.

7. An electric circuit breaker of the gas-blast type comprising:
(a) a pair of spaced-apart electrodes between which an arc is established during circuit interruption,
(b) an orifice having an opening through which said arc is adapted to extend when present between said electrodes,
(c) means for causing a stream of gas to pass through said orifice opening axially of said arc about the periphery of the arc,
(d) means for mounting the electrode upstream from said orifice for movement toward and away from said orifice,
(e) said upstream electrode having a normal position spaced by a relatively large amount from said orifice,
(f) actuating means responsive to arcing current above a predetermined value through said upstream electrode for moving said upstream electrode from its normal position toward said orifice, whereby to increase the gas velocity in the region between said orifice and said upstream electrode,
(g) means for limiting movement of said upstream electrode toward said orifice after the spacing between said upstream electrode and said orifice has been reduced to a predetermined finite value by said actuating means,
(h) and means responsive to a reduction in said arcing current to a predetermined level for returning said upstream electrode to its normal position, thereby reestablishing said relatively large amount of spacing between said orifice and said upstream electrode.

8. The circuit breaker of claim 7 in combination with:
(a) an auxiliary blast passage extending through said upstream electrode,
(b) a normally-closed auxiliary blast valve for controlling flow through said auxiliary blast passage,
(c) and means controlled by movement of said upstream electrode toward said orifice for opening said auxiliary blast valve to produce an auxiliary blast through said auxiliary passage during high current interruptions.

9. An electric circuit breaker of the gas-blast type comprising:
(a) a pair of spaced-apart electrodes between which an arc is established during circuit interruption,
(b) an orifice having an opening through which said arc is adapted to extend when present between said electrodes,
(c) means for causing a main blast of gas to pass through said orifice opening axially of said arc about the arc periphery during both high current and low current interruptions,
(c') said main blast flowing first past one of said electrodes, then through said orifice, and then past the other of said electrodes,
(d) an auxiliary blast passage extending through said one electrode from the region between said electrodes to a region of lower pressure,
(e) a normally-closed auxiliary blast valve in said auxiliary blast passage for controlling flow through said auxiliary blast passage and blocking flow therethrough when closed,
(f) means responsive to current through said breaker above a predetermined value for opening said normally-closed auxiliary blast valve during high cur-

rent interruptions to produce an auxiliary blast during high current interruptions that flows through said auxiliary blast passage from the region between said electrodes,

(g) and means for maintaining said auxiliary blast valve closed during low current interruptions.

10. The circuit breaker of claim **9** in which said current-responsive means of limitation (f) is responsive to current through said arc.

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ROBERT S. MACON, *Primary Examiner.*

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