June 2, 1942. D. C. PRINCE ET AL 2,284,842

CIRCUIT BREAKING APPARATUS

Filed Nov. 6, 1939 2 Sheets-Sheet 1

Fig. 1.

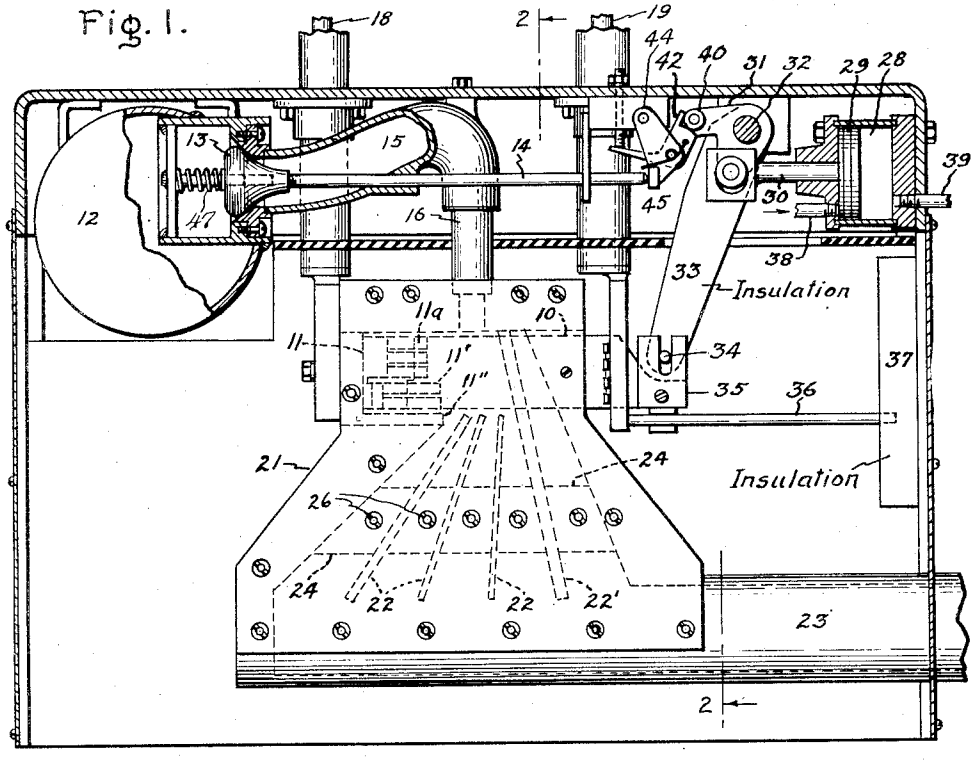


Fig. 2.

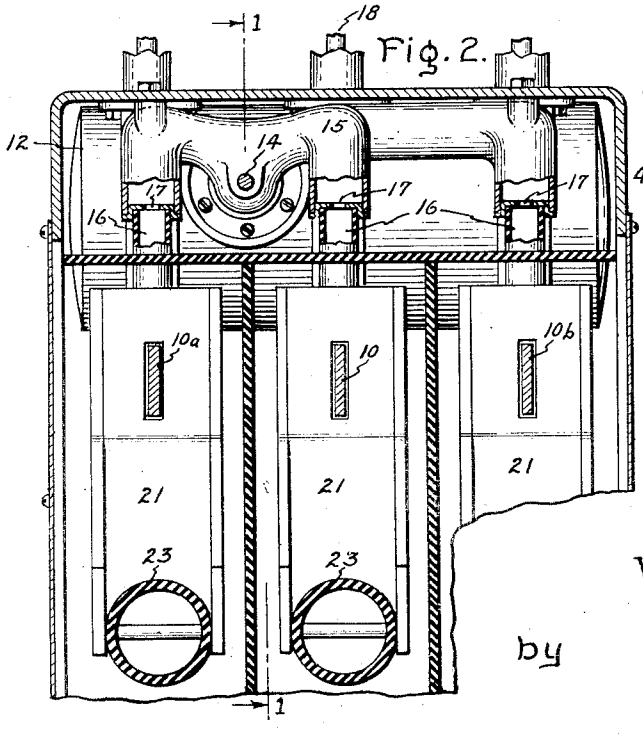
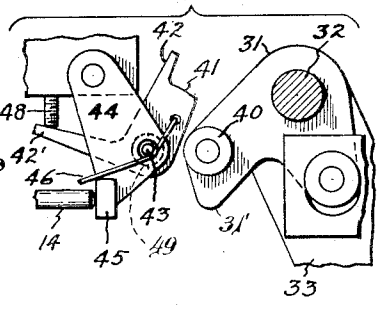


Fig. 3.



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Fig. 4.

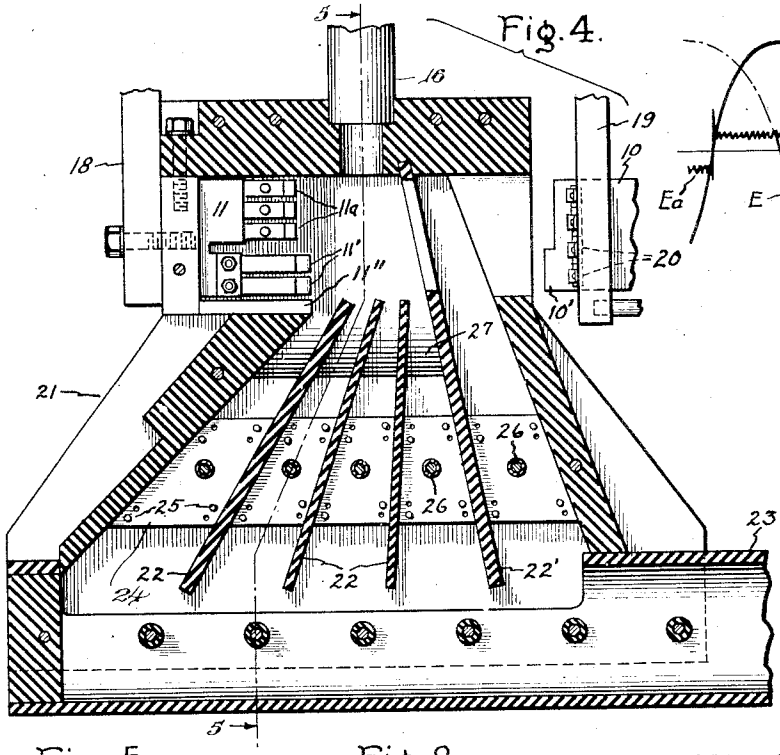


Fig. 7.

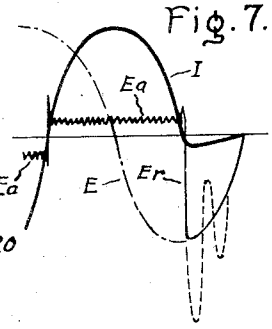


Fig. 5.

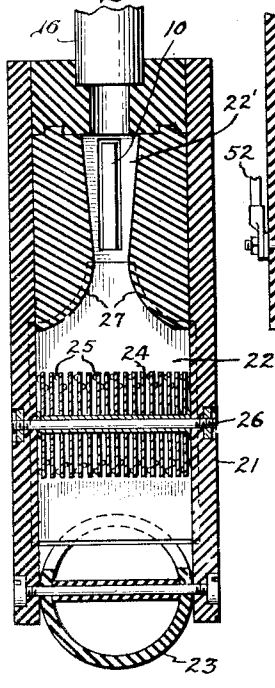


Fig. 8.

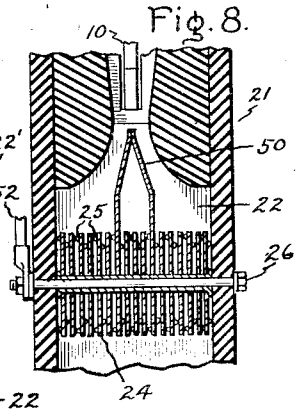


Fig. 6.

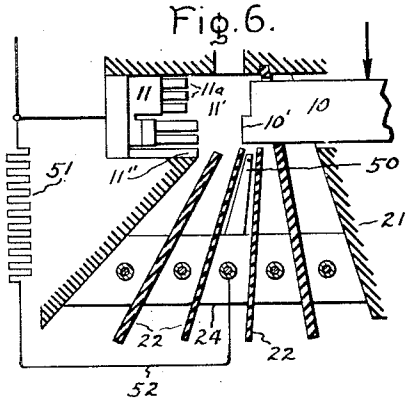
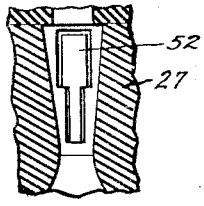


Fig. 9.



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UNITED STATES PATENT OFFICE

2,284,842

CIRCUIT BREAKING APPARATUS

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Application November 6, 1939, Serial No. 303,126

20 Claims. (Cl. 200—148)

Our invention relates to improvements in circuit breaking apparatus. Our invention more particularly relates to the interruption of the circuit by means of apparatus employing a blast of air or other gas to extinguish the arc formed when the circuit is broken between relatively movable contacts, but some features of construction and operation are applicable to other types of circuit interrupting apparatus for example circuit breakers in which a blast of fluid, such as oil for example, is used to extinguish the arc between such contacts, and certain features are adapted to circuit breakers of types not depending on a blast of gas or fluid as for example oil circuit breakers in which the contacts are merely separated in oil. More particularly our invention relates to an improved construction in which a blast of gas is directed at high velocity transversely across the arc gap formed between the separating circuit interrupting contacts to extinguish the arc.

Among the objects of our invention are to provide a circuit breaker adapted to interrupt high power alternating current electric circuits in which high interrupting capacity is combined with reliability, economy, small size, low first cost, low cost of maintenance; flexibility in the sense of being adapted for top, bottom, or side connection to the power circuit and mounting in cubicles with elevating mechanism or mounting in so-called trucks, and with complete freedom from any fire hazard which exists where circuit breakers use oil or other liquid which may burn or produce explosive and inflammable gases.

A further object is to provide a construction which will permit the main contacts continuously to carry high currents without overheating and which will enable far larger currents at high voltage to be interrupted than has been possible with any prior oilless circuit breakers with which we are familiar.

Further objects of our invention include a construction and mode of operation which permit circuits having an inherently high rate of rise of recovery voltage to be successfully interrupted without difficulty from the tendency of the arc to restrike between the separating contacts after it has been interrupted at a zero point of the alternating current wave of the circuit, and to reduce the rate of rise of such recovery voltage to facilitate the final opening of the circuit and reduce the stress on the insulation of adjacent live parts of the apparatus thereby preventing breakdown from high voltage surges, otherwise incident to such circuits, and to facilitate the closing of high voltage circuits by preventing or reducing the tendency of the circuit voltage to jump across the space between the contacts just before they engage each other in the closing operation, thereby reducing the forces necessary to close the breaker and also the burning of the contacts and voltage surges on the system during the closing operation.

These and other objects and advantages of our invention will be apparent from the following description and claims.

Heretofore, the use of air circuit breakers for interrupting high voltage power circuits has been limited to a few types, the more important being the axial flow type of air blast circuit breaker, an example of which is disclosed in Letters Patent to Ruppel No. 1,898,900 of February 21, 1933; the magnetic blowout type for heavy duty railway service having the arc chute construction of Letters Patent to Tritle No. 1,398,981 of December 6, 1921, well-known to the trade as type "JR" and the so-called "de-ionizing" type also well-known to the trade and employing a magnetic blowout field with arc dividing and cooling structure disclosed in Letters Patent to Slepian No. 1,784,760 of December 9, 1930. The largest "JR" type breaker thus far attained can successfully interrupt an alternating current from 40,000 to 50,000 amperes at 15,000 volts.

The largest "deionizing" type circuit breakers so far achieved interrupt an alternating current of 40,000 amperes at 26,000 volts, and no higher current at 15,000 volts. This type of air circuit breaker and the "JR" type of circuit breaker just referred to, have been under intensive study for years without its having been found possible, as far as we know, to extend the capacity limits here mentioned, although oil circuit breakers are in daily operation which will interrupt 100,000 amperes.

The axial flow type of air blast circuit breaker has been built up to 220,000 volts but no air circuit breaker of any type known to us has heretofore been built which would successfully interrupt more than 50,000 amperes at voltages even as low as 2,300 volts. The circuit breaker of the invention described in this specification has successfully interrupted 78,000 amperes at 4,200 volts, and such circuit breakers are under construction intended to interrupt 60,000 amperes at 15,000 volts, and we believe that in accordance with our invention, circuit breakers can be built

for at least twice this current and voltage, should they be required.

A circuit breaker embodying the cross blast features of our invention with an air supply of 120 lbs. per square inch has successfully interrupted for example 78,000 amperes with a voltage recovery rate of 280 volts per microsecond. The amount of air consumed per circuit interrupting operation of our circuit breaker in interrupting the 78,000 amperes was approximately 10 cubic feet of free air for all three phases of the three-phase circuit breaker.

In practicing our invention, we prefer to embody a small tank in the circuit breaker containing sufficient air for one or two complete closing and opening operations so that air will be available for operation of the circuit breaker in the event that there is some temporary failure of the main air supply system, but our invention is not concerned with the air supply except as far as concerns the supply from the local or individual tank to the circuit breaker as will be hereinafter described. The air supply system for air blast circuit breakers would ordinarily consist of a large storage tank and a compressor for maintaining the air pressure in that tank at about 250 lbs. per square inch, the size of the tank being sufficient for a bank or several banks of circuit breakers. This large tank from which most of the moisture in the air is drawn off as condensate, will feed a smaller tank through suitable piping including a reducing valve which will reduce the pressure to about 150 lbs. per square inch in the smaller tank. The smaller tank through one or more headers will supply air to the individual local tanks, one of which is embodied in each circuit breaker, a non-return or check valve being used between each individual tank and the header to which it is connected so that the individual tank will not lose its air to the header in the event of a break or leak in the supply system. Such non-return valve arrangement is disclosed in Letters Patent to Ruppel No. 1,874,808, dated August 30, 1932. The elimination of moisture from the air supply as described results in a supply of air for the air blast which is relatively dry and of high dielectric strength. Dust and other particles are filtered out at the compressor so that the large tank is supplied with clean air.

The main application of our invention at present will probably be for indoor circuit breakers. Since it does not utilize oil or other inflammable liquid our circuit breaker is ideal for such indoor application from the standpoint of fire hazard, but while our circuit breakers are intended primarily for station use, they can also be employed for outdoor designs and for higher voltages.

Our invention will be better understood from the following description and accompanying drawings, in which Fig. 1 is a side elevation and section taken on the line 1—1 of Fig. 2 showing one form of a circuit breaker embodying our invention, the contacts being shown in the position they occupy when the circuit is closed. Fig. 2 is a view taken on the line 2—2 of Fig. 1 looking in the direction of the arrows, Fig. 3 is a view of some of the mechanism of Fig. 1 slightly enlarged, Fig. 4 is an enlarged view showing a longitudinal section through the arc chute and showing the circuit breaker contacts in the open position, Fig. 5 is a sectional view on the line 5—5 of Fig. 4 looking in the direction of the arrows, Fig. 6 is a diagrammatic view showing an auxiliary spark gap and resistor connection of our invention, Fig. 7 is a diagram illustrating arc current, arc voltage, generated voltage, and curves of recovery voltage, Fig. 8 is an enlarged view in section showing more in detail the structural mounting of the auxiliary spark gap electrode, and Fig. 9 is a view of a modification showing a movable contact of different contour from that shown in Figs. 1, 2, and 3.

Referring to Fig. 1, the movable contact is shown at 10 and the co-acting fixed contact at 11. The movable contact is moved longitudinally to separate it from the fixed contact by any suitable mechanism, one example of which will be hereinafter described. Fig. 4 indicates the positions of the contacts when the movable contact 10 has entirely completed its movement of separation from the fixed contact. A three-phase circuit breaker embodies three such sets of relatively movable contacts, one set for each phase. Fig. 2 shows the contact 10 in section, the corresponding contacts for the other two phases being shown at 10*a* and 10*b*. The individual or local tank for supplying the air for the air blast for interrupting the arcs formed upon separation of the contacts of each of the three phases is shown at 12. A valve 13 is moved to open position by rod 14 to permit discharge air from the tank into a manifold 15. Three separate air conduits 16 branch from the manifold for supplying an air blast respectively to each of the three sets of contacts. Each conduit is provided with an orifice 17 located upstream a short distance from the arc gap formed between the contacts 10 and 11 for a purpose hereinafter described.

Referring to Figs. 1 and 4, it will be observed that each air conduit 16 is in a position to direct a blast of air transversely across the arc gap formed upon separating the relatively movable contacts 10 and 11. In the construction illustrated in Figs. 1, 2, 4, and 5 the movable contact is a long blade-like member having a substantially rectangular section thin in one dimension but sufficiently wide in the other dimension to provide copper to carry high currents. This enables the co-acting contacts to serve as the main current-carrying contacts while the circuit is closed, as distinguished from a construction in which the contacts which break the circuit, commonly called arcing contacts or interrupting contacts, have to be supplemented by additional contacts commonly called the main contacts in order that the breaker may carry the full rated current continuously without overheating.

The fixed contact 11 is connected to the line terminal 18 and the movable contact 10 is connected to the line terminal 19, there being a corresponding pair of terminals for each phase of the circuit breaker. The wide, lateral surface area of the movable contact 10 facilitates conducting high currents into it by contact means bearing on such surface, such means being diagramatically indicated in Fig. 4 as a series of roll shaped brushes 20 held in place by flat springs. Similar roll shaped contacts bear on both sides of the moving contact. In the closed position of the switch shown in Fig. 1 the movable contact 10 is seated between suitable spring-pressed contact fingers 11*a* of the fixed contact 11. The final separation between the fixed and movable contacts occurs between the longer arcing contact fingers 11′ of the fixed contact 11 and an arcing tip 10′ of the movable contact 10, so that when the contacts separate any arc there-

between occurs between the arcing tips 10' and 11'. Immediately after separation of the contacts, one terminal of the arc is transferred by the air blast from the contact fingers 11' to the arcing member 11'', which is provided with a tip of arc-resistant metal.

The air blast drives the arc into the arc chute 21 against the edges of a plurality of partitions 22 in the arc chute, which partitions are transverse to the arc gap and the ends of which extend close to the path of movement of the arcing tip 10' of the movable contact 10. As shown in the drawing, the ends of the arc chute 21 are flared from the throat or entrance portion to the exit portion of the arc chute, which may lead into a suitable conduit 23 through which the gases are led to the exterior of the cubicle in which the circuit breaker is mounted. It will be observed that the partitions 22 are also similarly flared away from each other so that the arc chute is divided into a number of separate passages, into and through which the air blast directs the arc and hot gases and vapors. The walls of the arc chute and the partitions are of insulating material as hereinafter described. The arc, in being forced against the end transverse edges of the partitions 22, is stretched around said edges. This lengthens the arc path and tends to cut it as it moves into the chute. Owing to the flaring arrangement of the ends of the chute and the partitions, the cross sectional area of the passage in the arc chute increases rapidly from the entrance to the exit portions. This permits the hot arc gases and vapors to expand and thereby cool as they traverse the passages of the arc chute. We preferably provide additional cooling means of high heat absorbing capacity, and provided with relatively narrow openings or pores through which the gases and vapors may readily pass on their way to the exit portions of the arc chute. Such additional cooling means is shown in the drawing at 24 in Figs. 1 and 4, and more clearly in the enlarged cross sectional view constituting Fig. 5. As there shown, the cooling means is made up of a series of metal plates such as copper, spaced from each other in any suitable way, as for example by small projections 25, so as to permit the arc gases and vapors readily to pass there-between. These plates are shown as secured in place on bolts 26 which also serve to assist in securing the sides of the arc chute together. The flaring passages and the cooling plates which supplement the cooling action of the flaring passages so reduce the back pressure that would otherwise be built up in the arc chute that a high velocity of the air blast can be maintained across the arc gap and against the end portions of the partitions 22 at the entrance end of the arc chute.

The fact that the movable contact blade 10 is thin, makes it possible to make the throat at the entrance portion of the arc chute narrow so that the air blast is concentrated at the exact place where it should be of high velocity, namely, at the path of separation between the arcing tips 10' and 11' and the closely adjacent ends of the transverse partitions 22. As shown more clearly in Fig. 5, the members 27 in the portion of the arc chute through which contact 10 moves converge from the base of the arc chute, into which the air blast is delivered, toward the entrance portion of the chute proper in which the partitions 22 are located. With this construction air from the conduit 16 may freely enter the passage through which the contact 10 moves, flowing along the sides of the contact but being concentrated in the narrow cross section of the gap between the arcing tips 10' and 11' formed when the contacts begin to separate.

All parts of the arc chute including the members 27 and the walls of the arc chute are either made of insulating material or lined with insulating material which will withstand the heat and voltage consequent to operation. Parts in contact with the arc and particularly the end portions of the partitions 22 adjacent the arc path must be made of an insulating material which will withstand extremely severe conditions. The arc is not only driven by the air blast against the end edge portions of the partitions 22, but is bent around these edge portions into the passages between the partitions so that the edge portions are continuously subjected to the enormous temperature of the arc until the arc is broken. We have discovered that a suitable insulating material for withstanding these severe conditions is a fiber insulation such as hard white vulcanized fibre, which is a cellulose product having a moisture content of 4 to 7 per cent, zinc chloride less than 0.2 per cent, ash-red 5 per cent, all other ash 1 per cent, and otherwise pure cellulose. The required properties of a suitable material are that it must not become conducting when heated and it must not char so that the surface loses its insulating properties. Also metallic disposition on the surface of the material should not take place. These requirements are met by hard pressed fibre such as described and methyl methacrylate and it is probable that certain urea resins may be suitable. Surprising as it may seem, such highly refractory materials as porcelain, quartz, and temperature resisting glasses, such as those known to the trade as "Pyrex," are, we find, quite unable to withstand the severe arc conditions. Our tests indicate that one of the essential requirements is that the insulating material be of a character which will vaporize and thereby protect itself from the heat of the arc while subjected to the arc temperature. A helpful analogy in understanding how such protection may take place is that of the drop of water falling on the top of a red hot stove. The drop of water skitters across the stove without at once turning as a whole into vapor by reason of the fact that the body of the drop is insulated from the hot surface by a thin layer of steam between the drop and the stove. The cooling effect due to evaporation into steam keeps the body of the drop of water relatively cold so that it is not immediately destroyed. This action is known in physics as the spheroidal effect.

The di-electric strength of air is approximately 50,000 volts per inch. Its di-electric strength is no different whether it is still or in motion, but a high velocity blast directed into the arc gap between the separating contacts and against the ends of the partitions 22 is highly effective in interrupting the arc because it not only sweeps out the arc and arc products, but interposes fresh air of high di-electric strength at such a high rate as to prevent re-striking of the arc when it has once been interrupted at a current zero. We shall hereinafter more fully discuss what is meant by rate of rise of recovery voltage, but at this point it will be sufficient to say that a break in the arc path which is caused by interposition at a rate of 1,000 ft. per second—approximately sound velocity—of air having a di-electric strength of 50,000 volts per in. will

withstand a rate of recovery voltage rise of 600 volts per microsecond. With our construction in which the ends of the insulating partitions are close to the arc, the arc tends to be cut or divided at a number of points along its length. When the current reaches a zero point of the alternating current wave, fresh di-electric is being interposed so rapidly along each side of each partition edge that even higher rates of rise of recovery voltage will be precluded from restriking the arc after current zero even though the velocity of the blast may be much lower than the velocity of sound.

A high velocity of air in the gap between the electrodes and across the ends of the partitions is greatly facilitated by the flared construction of the arc chute passages and the supplemental cooling plates **24** which have been described, because these features greatly reduce back pressure which would otherwise obtain and militate against the desired high velocity of blast in the restricted throat of the arc chute in which the contacts separate.

The cooling plates **24** are arranged sufficiently remote from the entrance to the passages in the arc chute to preclude damage to these metal plates by exposure to the extremely hot gases before some cooling has taken place, but are arranged sufficiently close to the arc gap for high initial heat transfer. The cooling plates are located sufficiently remote from the exit end of the arc chute so that the projecting ends of the partitions afford sufficient insulation against breakdown outside the arc chute. The flaring arrangement of the partitions increases the length of any such breakdown path and the fact that the cooling arrangement tends to deionize any gases which emerge from the arc chute also lessens any danger of breakdown outside the arc chute.

The fact that the partitions **22** in the arc chute effectively separate the flaring passages from each other throughout their length clear down to the throat of the structure will be apparent when it is pointed out that the side edges of the partitions extend into tight grooves in the front and back walls of the chute structure. The grooves for one of the plates **22** are indicated in dotted lines in Fig. 5, and it will be observed that the end of this partition **22** adjacent the arc gap is seated in grooves in the members **27** so that there is no chance for the arc or any of its products to sneak from one passage to another around the sides of the partitions. On the contrary, the arc is forced against the end transverse edges of the arc chutes in the narrow throat portion adjacent the arc.

We will now describe the mechanism illustrated for operating the movable contact **10** into and out of engagement with the fixed contact **11** to make and break the circuit and for operating the valve **13** which admits air from the local storage tank **12** to the manifold **15** which distributes the air to the respective conduits **16** for the respective phases of the circuit breaker. It will be understood that our invention is not limited to any particular type of mechanism for operating the movable contacts whether that mechanism be, for example, electrical, mechanical including springs, or pneumatic. The mechanism illustrated is of the pneumatic type which may be conveniently used with our invention since the air for arc interruption is also available to operate such pneumatic mechanism.

As shown in Fig. 1, a cylinder **28** is provided with a piston **29** connected through a rod **30** to operate a lever **31** secured to the shaft **32**. The shaft has three arms **33** secured thereto, one of which is shown in Fig. 1 for operating the movable contact **10** of one of the phases. Similar arms are mounted on the shaft **32** for operating the movable contacts **10a** and **10b** of the other two phases. The arm **33** is shown provided with a pin **34** operating the member or block **35** secured to the outer end of the contact **10**. The block **35** is arranged to slide on a pair of rods **36** one of which is shown in Fig. 1, the other not appearing in that figure because it is behind the one shown. One end of each of the rods **36** is supported from the terminal **19** while the other ends of the rods are supported in a block of insulation **37** mounted on the switch structure. It will be apparent that when the shaft **32** is turned counter-clockwise the arm **33** will move the contact **10** to the open position and that when the shaft **32** is turned clockwise the arm **33** will move the contact **10** to the closed position. The block **35** and rods **36** constitute a kind of crosshead arrangement upon which the movable contact is reciprocated. In its movement the edge of the switch blade **10**, while within the arc chute, bears upon the edge of an opening in the insulating partition **22'** which has an opening therein only slightly larger than the switch blade. The opening in this partition **22'** is shown in end view in Fig. 5, and can also be seen in Fig. 4.

In Fig. 1 the switch is shown in the closed position. Upon introduction of air through a suitable control valve into the pipe **38** the piston **29** is moved toward the right of Fig. 1 air being exhausted through the pipe **39**. For operation in the other direction air is introduced into pipe **39** and exhausted through the pipe **38**.

The lever **31** mounted on the shaft **32**, in the arrangement shown, operates the mechanism opening the air valve **13** to initiate the air blast when the circuit interrupting operation starts. As appears more clearly from Fig. 3 the lever **31** carries a roller **40** which in the position shown in Fig. 1 is held by a cam surface **41** on the member **42** which is supported by a bearing **43** on a swinging arm **44** which has a projection **45** thereon which engages the rod **14** which operates the air valve **13**. A spring **46** around the bearing of the member **42** tends to hold the tail **42'** of the member **42** against a stop-pin **48** mounted on the supporting structure of the circuit breaker.

Starting with the circuit breaker in the closed position as shown in Fig. 1, upon introduction of air into the pipe **38** the piston **29** is operated to turn the shaft **32** counter-clockwise. The roller **40** on the lever **31** pushes down on the cam surface **41** of the member **42** to swing the member **44** clockwise about its pivot, and the projection **45** of the member **44** moves the rod **14** to open the valve **13** and admit the blast of air. The swinging arm **44** is forced by the roller **40** bearing on the cam surface **41** to swing in the manner described to carry the projection **45** toward the left by reason of the fact that the tail **42'** of the member **42** is bearing against the stop **48** preventing the member **42** from moving about its bearing **43** at this time thus preventing the roller **40** from slipping off the cam surface during this phase of the operation.

The turning of the shaft **32** counter-clockwise moves the arm **33** to separate the contact **10** from the contact **11** to break the circuit between these

contacts while subjected to a high velocity blast of air as heretofore described.

The arc will be interrupted before the end of the movable contact 10 has been drawn through the opening in the partition 22', but the contact in accordance with our invention continues to move through the opening in the partition 22' and ultimately through the side of the arc chute chamber until it is completely withdrawn from the arc chute structure as shown in Fig. 4. In this position the contact may be inspected without dis-assembly of the circuit breaker. Furthermore there are no short creepage surfaces so that it is easy to obtain excellent insulation characteristics. Any hot gases or vapors which may exist in the arc gap after the end of the contact 10 has been drawn through the partition 22' will be blown out through the arc chute passage formed between the partition 22' and the end wall of the arc chute. The opening in the arc chute structure through which the movable contact is finally withdrawn is also a relatively narrow opening so that its sides come close to the sides of the contact 10 insuring that a relatively high gas pressure will exist in the last or right-hand passage of the arc chute until the hot gases in the interrupting chamber have been completely exhausted therefrom and driven through the passages of the arc chute before the movable contact is entirely withdrawn from the structure.

It will be observed that since the arc is interrupted before it reaches the partition 22', the highly heated arc gases driven by the air blast into the chute are mostly confined to the first one or two chute passages. Therefore, the last passage at least, i. e. the passage defined by the partition 22' and the adjacent partition 22, is available to direct comparatively fresh and cool blast air into the chute. Since the hot arc gases directed into the exhaust conduit 23 near its closed end must mix with this cool air in leaving the conduit or exhaust chamber, it will be apparent that the exhaust gases are appreciably cooled. Flame emission from the conduit in the case of heavy duty operation is thereby greatly minimized. Such gas cooling and flame-controlling means are not claimed in this application but are disclosed and claimed in Letters Patent No. 2,272,224, granted February 10, 1942, to W. K. Rankin for Gas blast electric circuit breaker, and assigned to the same assignee as the present invention.

Near the end of the turning movement of the shaft 32 the roller 40 on the lever 31 slips off the cam surface 41 of the member 42 and the swinging arm 44 together with the member 42 which it carries, are returned to the position shown in Figs. 1 and 3 by the rod 14, which is pushed against the projection 45 on the swinging arm 44 by the action of the spring 47 bearing against the valve 13 and tending to close it. The air blast is thereby shut off. In actual practice the arc is interrupted before the movable contact 10 passes through the opening in the partition 22' but the valve is left open long enough so that the air under pressure in the manifold will expel the hot gases and vapors through the passages in the arc chute as heretofore described, before the contact 10 finally moves out of the opening in the side of the arc chute. The movement of the contact 10 is preferably slowed down as it goes through the partition 22', as by a suitable dash pot on the mechanism so that the hot gases will be fully discharged through the arc chute before the contact leaves the chute structure.

To close the circuit breaker, air is introduced into the pipe 39 to move the piston 29 toward the left, and were it not for a projection 31' on the lever 31, the roller 40 on the lever 31 would merely turn the member 42 on its pivot 43 against the action of the spring 46 without swinging the member 44 to open the air valve 13. However, it is desirable to direct a high velocity blast of air through the circuit breaker just before the arcing tip 10' of the movable contact 10 engages the arcing tip 11' of the fixed contact 11. The projection 31' on the lever 31 accomplishes this purpose by engaging a roller 49 on the bearing shaft 43 of the member 42. The roller 40 and the member 42 are in one plane, while the projection 31' and the roller 49 are in another plane, the roller 49 being shown in dotted lines in Fig. 3 because it is behind the member 42. When the shaft 32 turns in the clockwise direction to close the contacts of the circuit breaker, the projection 31' through a short range of its movement just before the arcing contacts 10' and 11' engage, comes against the roller 49 and swings the swinging arm 44 to the left to open the valve and admit a blast of air across the contacts of the circuit breaker. After the contacts of the circuit breaker have been engaged, the projection 31' slips off the roller 49 and the valve 13 closes by reason of the spring 47 in the manner heretofore described, and the parts are restored to the position shown in Fig. 1. The roller 40 slips into engagement with the cam surface 41 of the member 42 so that the parts are in position for another circuit interruption.

The length of time that the air blast is on during the closing operation can, by proper proportioning of the projection 31' and the roller 49, be made as long as desired. Where the circuit breaker is likely to be subjected to several opening and closing operations in short succession it will be very advantageous to have the air blast supplied not only near the end of the closing operation but throughout the larger part of the closing operation in order that the parts inside the arc chute, including the cooling plates 24, shall be prevented from rising to too high a temperature.

As we have pointed out, the movable contact 10 moves longitudinally to engage the fixed contact 11 and bridge the circuit between the circuit terminals 18 and 19. This arrangement of contacts provides freedom from electro-magnetic effects tending to prevent closing of the circuit. The circuit from the terminal 18 through the terminal 19 constitutes a loop in the electrical circuit, and action of the magnetic forces in any such loop is always in the direction to straighten out the loop. The terminals 18 and 19 can easily be mounted in a structure with sufficient rigidity to prevent their movement by the magnetic forces, and the magnetic forces tending to move the switch blade 10 are not in a direction to prevent closing of the circuit but in a direction to force the switch blade against its supporting structure on the terminal 19 and against the end of the partition 22' on which it bears. Therefore the magnetic force on the part of the loop represented by the bridging contact 10 is not in a direction to cause any difficulty. This is in contrast with the forces which would appear on this contact were it raised vertically to close the circuit between terminals 18 and 19, as is the case in many conventional oil circuit breakers where such a bridging member is raised to close the circuit and lowered to

open it. Our arrangement makes it possible to close the circuit against much higher currents than can be closed with oil circuit breakers of such conventional design, as high as 125,000 amperes have been closed with circuit breakers of our design.

We have referred to the orifices 17 in the conduits leading from the manifold 15 to the sets of contacts in each phase of the circuit breaker. The use of such an orifice is an important feature of our invention and it has a number of very advantageous effects. The required air pressure for the cross blast chute is quite low being of the order of 50 pounds per square inch depending on the back pressure. Due to the excessive size that would be required of low pressure storage tanks, it is economical to store air at higher pressures, for example at 150 pounds per square inch. An orifice has the property, when supplied with gas at a constant pressure, of discharging a constant amount of air per minute against any back pressure less than 53 per cent of the tank pressure. In accordance with our invention, air is stored at say 150 pounds per square inch and is discharged into the arc chute of each phase through an orifice of just the right size to deliver the right amount of air. Substantially that amount of air will then flow regardless of variations in back pressure as long as the back pressure is less than 53 per cent of the tank pressure. Each orifice therefore delivers the proper amount of air, and the division of air between the conduits leading from the orifices to the separate phases is not spoiled by varying lengths or shapes of the delivery conduits, nor is it made unequal by different currents in different phases at the time of interruption causing the back pressure of any one phase to be less than that at the other phases, or either of them. Our arrangement therefore provides an adequate supply of high velocity air for interrupting high currents without being unduly wasteful of air when small currents are to be interrupted. The orifice means defines a constricted portion in each gas supply conduit adjacent the region of arcing and upstream therefrom so that the gas and the arc do not both pass through the constricted portion.

This feature of our invention is not limited to cross blast circuit breakers, but is applicable with great advantages in the axial flow type of air blast circuit breaker. The axial flow type suffers a rapid loss in its ability to handle circuit recovery voltage as the interrupting current increases. This is due to the fact that back pressure from the arc serious reduces the flow of fresh air from the storage tank. This requires such a high tank pressure for severe conditions that there is a tremendous waste of air for normal operation. With our orifice arrangement, if the amount of air can be made correct for the severe conditions, there will not be such a great waste of air for normal operation.

Our circuit breaker as heretofore described is very effective in handling circuits even with moderately high rates of rise of recovery voltage, but can be made still more effective and can be applied to power circuits having inherently any rate of rise of recovery voltage no matter how high, by the provision of an auxiliary electrode properly positioned to form a spark gap between it and the moving contact of the circuit breaker and a resistor of proper value connected in series with such spark gap to form a circuit in shunt to the arc when the spark gap breaks down due to the rise of recovery voltage following an interruption of the arc at a zero point of the power current wave.

Such an auxiliary electrode arrangement may also be effective in preventing the circuit voltage from causing the arc to spring between the circuit breaker contacts just before they engage each other while the circuit is being closed. This auxiliary electrode is shown at 50 in Fig. 6 and the resistor is shown at 51. One terminal of the resistor 51 is in electrical connection with the fixed contact 11 while the other terminal is connected through a conductor 52 to the auxiliary electrode 50. A convenient way of making the connection is through an extension of one or more of the cooling plates 24 as hereinafter described. It will be observed that the auxiliary electrode 50, in the arrangement shown, is positioned in the third arc chute passage. It extends to a point sufficiently near the contact blade 10 to form an arc gap having a resistance to break-down sufficiently great that no current traverses the resistor 51 prior to arc interruption at a current zero during the circuit opening operation. The auxiliary electrode is, however, sufficiently close to the path of movement of the moving contact 10 to permit recovery voltage appearing between the fixed and movable contacts 10 and 11 to break down the spark gap and establish a current path through the resistor 51 and the spark gap in series, before the recovery voltage has reached such a value as to restrike the arc.

The operation of the arrangement of auxiliary electrode and resistor may be more clearly understood by referring to Fig. 7, and a discussion of the curves shown in Fig. 7 will incidentally make clear what has been heretofore said about recovery voltage. In Fig. 7 the curve I represents the power current through the arc from a time just prior to and during the time of a circuit interruption. E represents the generated voltage wave which would appear across the contacts were they in the completely open position of the circuit breaker and no current flowing through the circuit. E_a represents the voltage appearing across the contacts while an arc is maintained, and E_r represents the recovery voltage appearing across the contacts, the dotted portion of the curve showing what curve the recovery voltage would take were our invention embodying the auxiliary electrode not present. The curves shown represent instantaneous values, and the entire time represented by the diagram is approximately the time taken for one cycle of the alternating current. The shortness of time represented by the entire diagram becomes apparent when it is borne in mind that one cycle of a 60 cycle alternating current power system represents $\frac{1}{60}$ of a second.

While the circuit breaker contacts 10 and 11 are in engagement carrying the circuit current there is practically no voltage drop at the contacts because the contact surfaces are so large as to have very low resistance. When the contacts separate and draw an arc the voltage E_a appears across the arc gap. The diagram shows that the arc was existent just prior to a zero point of the alternating current wave I. When the wave of current passed through the first zero the arcing tips of contacts were very close together, none of the dividing partitions was yet in operation and the arc was quickly re-established or in other words never interrupted. The current I continued to flow for a half-cycle with the rela-

tively low voltage Ea appearing across arc gap. If at the end of this half cycle the current had been absolutely prevented from again flowing a voltage would have appeared across the gap rising at a very rapid rate represented by the steepness of the recovery voltage curve Er. It might have continued to rise as represented by the dotted portion of the curve Er to a high value approximately twice that of the generated voltage, and would then have rapidly decreased and then increased again, as indicated by the dotted form of the curve, until the oscillation was ultimately damped out. It might be supposed that if the current were interrupted at the zero point of the current wave there would be no voltage surge on the system, but the fact is that at the time of short circuit the resistance of the power circuit is very low while the inductance is relatively high so that the power current wave is substantially 90° out of phase with the generated voltage wave. Since the impedance is mainly inductive the current lags behind the voltage wave about 90° so that at the time the current is zero the generated voltage is at its maximum value. The voltage across the circuit breaker at this time is low but it will rise to the generated value as fast as permitted by the circuit inductance and capacity. The voltage, therefore, rises at an extremely rapid rate and charges the capacity in the circuit and then the capacity discharges back through the inductance of the circuit again, storing energy in the form of magnetism, and these oscillations continue until damped out by the resistance of the circuit. Since the natural resistance of the circuit through which the discharge occurs between the inductance and capacity is low it takes a number of cycles before these oscillating currents are damped out although the total time taken is very short.

The rate of rise of recovery voltage may be so rapid that the gap between the circuit breaker contacts will be broken down and a new power arc started between the contacts after a current zero. Our air blast circuit breaker is so effective that circuits having a relatively high rate of recovery voltage that might cause restriking of the arc in less effective types of circuit breakers, are satisfactorily interrupted at a current zero. But there are circuits which have rates of rise of recovery voltage of 15,000 to 20,000 volts per microsecond. Such very high rates are rare although rates as high as 10,000 volts per microsecond may not infrequently have to be dealt with. Our auxiliary electrode and resistor arrangement makes it possible for our circuit breaker to interrupt circuits having any rate of rise of recovery voltage. It accomplishes this result by reducing the rate of rise of recovery voltage to a value that is within the capacity of the circuit breaker to handle without difficulty.

We will now describe the operation of our auxiliary electrode and resistor arrangement starting with the circuit breaker contacts **10** and **11** in the closed position. When the contacts begin to separate, the arc is immediately transferred to the arcing tips and driven across the ends of the arc chute barriers as heretofore described. During this time the arc voltage is not high enough to break down the spark gap between the auxiliary electrode **50** and the movable contact **10**. When, however, the arc has been interrupted at a current zero the appearance of recovery voltage is accompanied by breakdown of the spark gap. The energy in the circuit is permitted to discharge through the spark gap and resistor so that the recovery voltage is prevented from rising rapidly enough to restart an arc between the circuit breaker contacts. The auxiliary electrode is preferably positioned so close to the contact **10** that the recovery voltage is not permitted to rise to a value which will re-establish the arc. A resistor having a relatively high value of resistance is sufficient to limit the rate of rise of recovery voltage to a value well within the interrupting capacity of the circuit breaker. The resistor may, therefore, be made relatively small in physical dimensions and inexpensive correspondingly. The provision of our spark gap and resistor arrangement therefore adds little to the complication or expense of the circuit breaker but enormously increases its effectiveness in dealing with circuits having inherently high rates of rise of recovery voltage.

The value of the resistance of our resistor is far too high to permit it to have any functional or noticeable effect on the current in the arc between the circuit breaker contacts prior to a current zero. The resistor value in accordance with our invention is related not to arc properties prior to current zero, but to circuit breaker and circuit conditions subsequent to current zero. Subsequent to current zero each circuit breaker presents a strength against voltage breakdown which rises from a negligible value during the arcing period to the final insulation value of the circuit breaker when open. Each circuit breaker has its own individual characteristics but in general there is a limit to the rate at which voltage can be impressed subsequent to current zero without causing a breakdown and re-establishment of the arc between the contacts.

Our auxiliary electrode and resistor arrangement is not limited in its application to the cross blast type of circuit breaker which has been described, but it is applicable to axial blast circuit breakers and to circuit breakers in general. The proper value of the resistance for operation of the resistor and spark gap shunting circuit of our invention can be determined mathematically for circuits operating at a normal frequency of 60 cycles per second by the following formula:

$$R = 1880 \frac{rr}{I}$$

Where

R=the resistance in ohms.

rr=permissible rate of rise of recovery voltage in volts per microsecond.

I=R. M. S. current in amperes.

For example let it be assumed a particular circuit breaker is able to handle a rate of rise of recovery voltage of 200 volts per microsecond and that the current which this circuit breaker is to interrupt is 10,000 amperes. Substituting these values in the equation will give a value of R of 38 ohms. If this value is used for the resistor, then the rate of rise of recovery voltage across the circuit breaker contacts can never exceed 200 volts per microsecond no matter how high this rate of rise would have been in the natural, unmodified circuit. By this formula therefore, the value of a suitable resistor can be determined if the recovery characteristic of the circuit breaker is known in volts per microsecond.

As the rate of rise of recovery voltage is reduced due to insertion of the resistance, the curve Er, Fig. 7, becomes less steep and the peak recovery voltage approaches the value of the line voltage indicated at E. Accordingly, voltage

breakdown and re-establishment of the arc between the separated main contacts **10** and **11** can be easily prevented by the air blast in our circuit breaker. The small current which begins to flow through the resistance **51** upon breakdown of the gap between the auxiliary electrode **50** and the contact **10** after interruption of the arc at a current zero is easily interrupted by the air blast and this interruption of the current through the resistance occurs without any re-establishment of any arc between the main contacts and about one-quarter cycle after the current zero at which the arc between the main contacts was interrupted, as shown in Fig. 7.

The cross blast circuit breaker of our design can be designed for any reasonable rate of rise of recovery voltage and can without special effort in the design handle rates of rise of from 100 to 1000 volts per microsecond so that a suitable value of resistance for the resistor when applied to our circuit breaker would be in one case

$$R=\frac{188,000}{I}$$

and in the other case

$$\frac{1,880,000}{I}$$

Our resistor in addition to performing its valuable function on circuit opening may perform an important function on circuit closing. For example, if the circuit in which the circuit breaker is to be used is one feeding a large transformer, there may be a tendency for a large current arc to jump across the contacts just before they reach the closed position. With our arrangement, the initial spark may jump from the electrode **50**. This tends to prevent the aforesaid arcing condition because, in general, the resistor will be of such high value as to impose a limitation on current flow.

As heretofore stated the auxiliary electrode **50** as shown in Figure 6 is connected to the metal cooling plates **24**. Fig. 8 shows a suitable construction more in detail in which two of the cooling plates which are near together are provided with extensions which are brought down and fastened together at the tip to provide a relatively rigid construction of the auxiliary electrode.

The movable contact **10** as heretofore described was shown as a thin, wide blade but if desired the current carrying capacity of the contact may be increased, while still maintaining the thin blade-like structure in the throat of the interrupting chamber, by enlarging the opposite side of the contact as shown in Fig. 9 at **52**. Any desired shape may be given to this part of the movable contact without reducing the effectiveness of our breaker as long as the blade-like structure is properly located in the throat of the arc chamber as heretofore described.

Since our circuit breaker does not contain any oil or other liquid it may be arranged for bottom connected terminals **18** and **19** instead of top connected terminals, as illustrated in the drawings, or may be turned on its side to bring the contacts out laterally. As heretofore stated this results in a flexibility of connection suitable for various types of cubicles.

It will be apparent to those skilled in the art that our invention is not limited to the particular construction shown, but that changes and modifications may be made without departing from the spirit and scope of our invention, and we aim in the appended claims to cover all such changes and modifications.

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

1. A gas blast circuit breaker for alternating current power circuits adapted to interrupt the current at substantially the zero point of the current wave comprising relatively movable contacts, means containing gas under pressure prior to separation of said contacts, means for supplying a blast of gas from said means substantially at right angles to the path of contact movement whereby the blast is directed transversely to the arc gap formed between the contacts upon separation thereof, an arc chute into which the arc is directed by the blast, said arc chute being constructed to facilitate the escape of gases and vapors therethrough with a minimum back pressure and being provided with a partition of insulating material dividing the chute into separate passages for the arc gases and vapors, said partition having its width transverse to the path of the arc and having its transverse insulating edge portion close to the path of contact movement whereby the arc path is stretched around said edge to lengthen and cut it as it moves into the chute, said transverse edge portion being composed of a vaporizable insulating material such as hard fibre as described, gas being introduced into the space between the contacts and against the edge of said partition at a velocity high enough to interpose dielectric in the form of fresh un-ionized gas at a rate sufficient to prevent the recovery voltage from re-striking an arc between the contacts after the circuit has been interrupted.

2. An electric circuit breaker of the gas blast type comprising relatively movable contacts for opening alternating current power circuits, means containing gas under pressure prior to separation of said contacts, means for directing a blast of gas from said means transversely across the arc gap formed upon separation of said contacts, an insulating arc chute substantially surrounding said arc and defining passages for said blast, said chute at the side of said arc gap opposite to the entrance of said gas blast having a plurality of partitions with their planes disposed transversely of the length of the arc gap and with their transverse end edges close to the arc gap so that said arc is driven by said blast directly against said edges and between said partitions so that the arc path is stretched around and cut thereby, the end edge portions of said partitions which cut the arc being composed of insulating material characterized by the ability to vaporize, as contrasted with fusing, under influence of the arc and thereby keep sufficiently cool to retain a high dielectric strength in the presence of the arc.

3. A gas blast circuit breaker for alternating current power circuits comprising relatively movable contacts, an arc chute having side and end walls providing an entrance opening closely adjacent to the contacts which opening is relatively long along the direction of the arc gap formed upon separation of said contacts and relatively narrow transversely thereto, said end walls diverging from each other from a point near to the entrance opening to provide an exit opening which is materially longer than the length of said entrance opening, a plurality of partitions spaced from each other in said arc chute and arranged transversely to the length of the arc gap, said partitions dividing the chute into a plurality of passages the cross sectional area of which in-

creases from a point adjacent the entrance opening to the exit opening, the ends of said transverse partitions at the entrance opening of said arc chute extending close to the arc gap and means containing gas under pressure prior to separation of said contacts, means for directing a blast of gas from said means transversely across said arc gap and into said arc chute so that the arc is driven against the end edges of said partitions and stretched into said passages while the back pressure is reduced due to the fact that the increasing area of the passages permits the gases to expand and cool, said cooling being sufficient so that with the increased length at the exit opening any voltage available between the contacts cannot strike an arc outside said arc chute, said ends of said partitions being composed of a vaporizable insulating material maintaining said edges non-conducting notwithstanding the action of the arc.

4. A gas blast circuit breaker comprising an arc chute having a narrow entrance portion and a diverging flared portion leading to exhaust, relatively movable contacts separable at said narrow portion to form an arc gap, means containing gas under pressure prior to separation of said contacts, means for directing a gas blast from said means into said narrow entrance portion for driving the arc into said chute, a plurality of insulating partitions mounted within said chute and extending edgewise from positions closely adjacent to said arc gap to the exhaust end of said chute, said partitions extending fan-wise from said arc gap with the lateral surfaces thereof substantially transverse of the length of said gap whereby are arc path is cut into series sections as it impinges under influence of said blast on the adjacent edges of said partitions, said partitions at the arc impinging edge portions being composed of a vaporizable insulating material adapted to remain non-conducting in the presence of the arc whereby the impinging edges of said partitions at said arc path are maintained at high dielectric strength during the entire arc interrupting operation, and metallic cooling structure having considerable mass and high heat conductivity, disposed between said partitions at positions intermediate the entrance and exhaust portions of said chute so that said structure is sufficiently close to said arc gap for high initial rate of heat transfer, and also is sufficiently removed from said gap to preclude damage to said structure from excessive heating or flashover upon opening of the circuit, said cooling structure also being sufficiently porous to permit free venting of said blast through said chute.

5. A gas blast circuit breaker comprising relatively movable contacts, means for directing a gas blast through the arc gap formed upon separation of said contacts to interrupt arcing, a source of gas under pressure for supplying interrupting gas to said gap, a conduit between said source and gap, and orifice means defining a materially constricted portion in said conduit adjacent said arc gap and upstream therefrom so that the gas and the arc do not both pass through said constricted portion for stabilizing the flow of gas to said arc gap notwithstanding wide variations in back pressure at said gap incident to low and high interrupting currents.

6. A gas blast circuit breaker comprising relatively movable contacts, means for directing a gas blast through the arc gap formed upon separation of said contacts to interrupt arcing, and a source of gas supply including a conduit leading to said arc gap, said conduit having a materially constricted portion located adjacent said arc gap and upstream therefrom so that the gas and the arc to not both pass through said constricted portion, said constricted portion being so constructed as to deliver to said gap at a back pressure not exceeding 53% of the source pressure a supply of gas substantially limited to the maximum requirement for interrupting said arc whereby an adequate supply of gas for all arcing conditions is delivered to said gap notwithstanding variation in back pressure due to arcing.

7. A polyphase gas blast breaker comprising a plurality of circuit breaker units, each of said units having relatively movable contacts and means for directing a gas blast through the arc gap formed upon separation of said contacts, a source of gas supply and a manifold leading therefrom to said circuit breaker units respectively, a valve for admitting gas from said source to said manifold each branch of said manifold having flow equalizing means comprising a constricted portion defining an orifice having such cross sectional area that an adequate and substantially uniform supply of interrupting gas tends to be delivered to its breaker unit during appreciable variations in back pressure due to arcing to prevent one breaker unit from depriving another breaker unit of an adequate supply of gas during a polyphase circuit interruption notwithstanding differences in the magnitude of the individual phase interrupting currents.

8. A circuit breaker for alternating current power circuits characterized by high rates of rise of recovery voltage upon interruption of the circuit, comprising relatively movable contacts, interrupting means associated with the arc gap formed upon separation of said contacts, and a resistance adapted to complete a shunting circuit between said contacts during the arc interrupting operation and adapted to complete said shunting circuit during any part of the closing operation during which the normal circuit voltage might cause a breakdown of the space between said contacts to occur said resistance having an ohmic value of approximately

$$\frac{1880\ rr}{I}$$

where rr is the rate of rise of recovery voltage in volts per microsecond for which the circuit breaker can be used with a proper margin of safety and I is the value in amperes of the current of the circuit to be interrupted.

9. A circuit breaker for alternating current power circuits characterized by high rates of rise of recovery voltage upon interruption of the circuit, comprising relatively movable contacts, interrupting means associated with the arc gap formed upon separation of said contacts, and a resistance adapted to complete a shunting circuit between said contacts independent of said arc gap during the arc interrupting operation and adapted to complete said shunting circuit during any part of the closing operation during which the normal circuit voltage might cause a breakdown of the space between said contacts to occur, said resistance having an ohmic value lying within the limits of

$$\frac{500{,}000}{I}$$

and

$$\frac{5{,}000{,}000}{I}$$

where I is the value in amperes of the current of the circuit to be interrupted.

10. A fluid blast circuit breaker particularly effective for interrupting an alternating current power circuit characterized by a high rate of rise of recovery voltage upon interruption of the circuit, comprising cooperating fixed and movable contacts, means for causing a fluid blast to traverse the arc gap formed upon separation of said contacts, a resistance one terminal of which is connected to said fixed contact, and an auxiliary electrode connected to another terminal of said resistance, said auxiliary electrode being so positioned with respect to said movable contact as to define therewith a spark gap having a breakdown potential sufficiently great that no current traverses said resistance prior to arc interruption at a current zero during the circuit opening operation but having a breakdown potential sufficiently small to permit recovery voltage appearing between said contacts to break down said spark gap and establish a current path between said contact through said resistance and spark gap in series before the recovery voltage has reached restriking potential said fluid blast causing the final interruption of the power circuit to occur at said spark gap said spark gap and resistance being arranged to permit current to flow in said current path independently of any arc in said arc gap.

11. A gas blast circuit breaker for alternating current power circuits comprising a movable contact and a co-acting contact for both carrying the power current and for breaking the circuit, an arc chute having a restricted entrance portion and a comparatively wide flared exhaust portion, said movable contact including a blade-like portion having substantially parallel sides with a large lateral contact surface area as compared with its edge surface area for engaging corresponding contact surfaces of said co-acting contact, said coacting contact surfaces normally carrying large power currents without overheating, means for operating said movable contact longitudinally into and out of engagement with said co-acting contact at said entrance portion for making and breaking the circuit, means defining a passage for directing a blast of gas into said restricted entrance portion transversely across the arc gap formed when said contacts separate, the walls of said passage defining said entrance portion and also lying close to the lateral sides of said blade-like portion so that the arc formed upon separation of said contacts is subjected to a concentrated blast of high velocity in a narrow slot-like space having a width corresponding to that of said blade-like portion, the flared exhaust portion of said chute greatly reducing the back pressure at said arc gap whereby the effectiveness of the blast at said arc gap to interrupt high current arcs is further increased.

12. A gas blast circuit breaker for alternating current power circuits comprising an arc chute having a restricted entrance portion and a comparatively wide flared exhaust portion, a movable contact having a thin parallel sided blade-like portion and a co-acting contact separable within said restricted portion to form an arc gap, means containing gas under pressure prior to separation of said contacts, means for directing a blast of gas from said means through said entrance portion and across said arc gap so as to exhaust at the flared end of said chute, said blade-like contact portion being longitudinally movable in a direction transversely of said gas blast, the minimum width of said restricted portion corresponding to the thickness of said blade portion whereby the arc formed upon separation of said contacts is subjected to a concentrated blast of high velocity in the narrow space previously occupied by said blade-like portion, a plurality of insulating partitions extending fan-wise from said space to said exhaust portion arranged so that the edges of said partitions tend to cut said arc into serially related sections as said arc is driven against and between said partitions by said blast, said edges of said partitions being composed of a vaporizable insulating material having the quality of retaining high dielectric strength in the presence of the arc, and heat absorbing means disposed between said partitions intermediate said entrance and exhaust portions adapted to absorb rapidly a large amount of heat from the exhaust gasses thereby reducing the gas volume in said chute, said heat absorbing means and flared chute portions con-jointly contributing toward lower back pressure in said chute for increasing the effectiveness of said high velocity blast at said arc gap.

13. A gas blast circuit breaker comprising an arc chute having a restricted entrance portion and a wide flared exhaust portion, relatively movable contacts separable at said restricted portion to form an arc gap, means for directing a gas blast into said restricted portion and through said arc gap to interrupt the circuit, a plurality of insulating partitions extending fan-wise from said restricted portions to said exhaust portion, said partitions being disposed so that the arc path tends to divide into serially related sections as it is driven against the edges of and between said partitions by said blast, metallic cooling structure having gas venting passages disposed between said partitions and spaced from the entrance and exhaust ends of said chute, an auxiliary electrode depending from one of said cooling structures to a position adjacent to the arc cutting edges of said partitions so that the extremity of said electrode is spaced a short distance from the path of movement of one of said contacts to form therewith a spark gap, and a resistance one terminal of which is connected to said electrode and another terminal to another of said contacts.

14. A gas blast circuit breaker for alternating current power circuits comprising an arc chute having an entrance portion and a flared exhaust portion, means for directing a gas blast to said entrance portion, said entrance portion including a narrow slot-like passage arranged to confine said blast to a narrow space so that it flows therethrough at high velocity, relatively movable contacts including a blade-like contact portion arranged for reciprocal movement in said slot-like passage so as to separate to form an arc gap in said slot-like passage transversely of said blast, and a plurality of insulating partitions extending fan-wise from said slot-like passage to said flared exhaust portion, the edges of said partitions being positioned closely adjacent to said arc gap and arranged so that said blast in traversing said passage and arc gap drives the arc against the edges of and between said partitions to cut the arc path into a plurality of serially related sections for interruption at a current zero, said gas blast thereupon interposing fresh dielectric in said narrow passage and between said partitions to prevent restriking of the arc, said partitions at the arc-impinging edge portions being composed of a vaporizable insulating material

having the quality of retaining high dielectric strength notwithstanding the action of the arc.

15. A gas blast circuit breaker for alternating current power circuits adapted to interrupt the circuit at substantially a current zero comprising relatively movable contacts, means for supplying a blast of gas substantially at right angles to the arc formed between the contacts, an arc chute into which the arc is directed by the blast, said arc chute having an entrance portion of elongated section along the longitudinal axis of which the arc is drawn upon separation of said contacts and having a flared exhaust portion comparatively wide with respect to the entrance portion to facilitate the escape of gases and vapors therethrough with a minimum back pressure, said arc chute having a plurality of insulating partitions dividing the chute into separate diverging passages for the arc gases and vapors, the width of said passages beyond said entrance portion being greater than the width of said entrance portion, said partitions being transverse to the line of separation of said contacts and including end edge portions thereof closely grouped and terminating substantially at the entrance portion of the chute, said end edge portions being composed of insulating material having the quality of passing from a solid to a vapor state at high temperature without fusing whereby the dielectric strength of said edge portions is maintained at a relatively high value throughout the circuit interrupting operation to minimize voltage breakdown at said gap, said gas supplying means directing the blasts into the space between the contacts to impinge against one or more of the edge portions of said partitions and supply fresh un-ionized gas at a rate sufficient to prevent the recovery voltage from restriking an arc between said contacts.

16. A gas blast circuit breaker comprising a fixed contact and a relatively movable blade contact, an insulating arc chute having a restricted entrance portion of slot-like section, the arc path formed upon separation of said contacts extending longitudinally of said section, a plurality of insulating partitions composed of a vaporizable insulating material such as hard fibre as described transverse to said arc path and forming separate gas exhaust passages in said chute leading from said slot-like entrance, the edges of said partitions at said entrance being closely grouped, a source of gas pressure for supplying a blast of gas transversely of and through said arc path and into said chute for extinguishing the arc, said blade contact extending longitudinally of said slot-like section with close clearance between the side portions of the blade contact and the side walls of said slot near one edge of said blade contact, said slot defining part of a blast passage in which said blade contact is disposed and arranged to be in communication with said source so that the arc formed between said contacts upon separation thereof is subjected to a concentrated blast of high velocity gas in said slot and driven against one or more of the transverse end edges of said insulating partitions where it is cut into series sections and extinguished.

17. A gas blast circuit breaker for power circuits comprising an elongated movable contact having ample cross sectional area to carry the full load current without overheating, said contact comprising a relatively thin blade-like portion and a relatively thick portion extending along one edge of said blade portion, said blade and thick portions having a large aggregate flat lateral contact surface area, a co-acting contact having means bearing on said lateral surface area to provide ample contact area when said contacts are fully engaged to carry the full load current without overheating, means for moving said movable contact longitudinally into and out of engagement with said co-acting contact for making and breaking the circuit, insulating means defining a passage for directing a blast of gas transversely across the arc gap formed when said contacts separate, the said thick portion being located upstream and said blade portion being located downstream with respect to the flow of gas traversing said passage, the walls of said passage lying longitudinally along the sides of said movable contact and converging from said thick portion toward the blade portion edge of said contact to define a narrow space appreciably beyond said thick portion in which the arc formed upon separation of said contacts is subjected to a concentrated interrupting blast of high velocity.

18. A gas blast circuit breaker for power circuits comprising an elongated movable contact having ample cross sectional area to carry the full load current without overheating including a blade-like portion having flat sides providing a large flat lateral contact surface area, a co-acting contact having means bearing on said lateral surface area to provide ample contact area when said contacts are fully engaged to carry the full load current without overheating, means for moving said movable contact longitudinally into and out of engagement with said co-acting contact for making and breaking the circuit, insulating means defining a passage for directing a blast of gas transversely across the arc gap formed when said contacts separate, said blade-like portion being positioned edgewise to said blast, the side walls of said passage lying longitudinally along the sides of said blade portion and converging toward each other so that the minimum passage width is approximately at the downstream edge of said blade portion, said side walls thereby forming a slot-like restriction in said passage having a width corresponding approximately to the thickness of the downstream blade edge portion, the arc formed upon separation of said contacts being subjected to a concentrated high velocity blast of said gas at said restriction.

19. A gas blast circuit breaker comprising a movable contact adapted to be connected to one line terminal and a co-acting contact adapted to be connected to another line terminal of a circuit to be interrupted, an arc chute having a relatively long narrow restricted entrance portion and a wide flared exhaust portion, said contacts being separable at one end of said narrow portion to form an arc gap, means for directing a blast of gas into said narrow portion and through said arc gap in a direction transverse to the length of the gap, a plurality of insulating partitions extending fan-wise from said narrow portion to said exhaust portion, said partitions being disposed transversely to the length of said narrow portion so that the arc tends to divide into serially related sections as it is driven against the adjacent ends of and between said partitions by said blast, an auxiliary electrode mounted between two of said partitions at a point spaced along said narrow portion from the point where said contacts separate and extending to a position adjacent to the arc cutting

ends of said two partitions with its extremity positioned only a short distance from the path of movement of said movable contact to form with said movable contact a spark gap adapted to be subjected to the gas blast between said two partitions, and a resistance connected between said electrode and the line terminal to which said co-acting contact is connected, said spark gap having a breakdown potential sufficiently high that no current traverses said resistance prior to arc interruption at a current zero during the circuit opening operation but having a breakdown potential sufficiently low to permit recovery voltage appearing between said contacts to break down said spark gap and establish a current path between said line terminals through said resistance and spark gap in series therewith instead of restriking the arc between said contacts.

20. A gas blast circuit breaker comprising relatively movable contacts, means for directing a gas blast through the arc gap formed upon separation of said contacts to interrupt arcing, a source of gas under pressure for supplying interrupting gas to said gap, a conduit between said source and arc gap, and orifice means in said conduit adjacent to said arc gap, said orifice means being constructed so as to provide a material constriction in said conduit which constriction is relatively short as measured along the longitudinal axis of said conduit, said orifice means being located upstream from said arc gap so that the gas and the arc do not both pass through said constricted portion.

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CERTIFICATE OF CORRECTION.

Patent No. 2,284,842. June 2, 1942.

DAVID C. PRINCE, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 31, for the word "disposition" read --deposition--; page 6, first column, line 55, for "serious" read --seriously--; page 7, first column, line 1, after "across" insert --the--; page 9, first column, line 36, claim 4, for "are" before "arc" read --the--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 21st day of July, A. D. 1942.

Henry Van Arsdale,

(Seal) Acting Commissioner of Patents.

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(Seal)