United States Patent [19]

Takasuna et al.

[11] **3,764,764**

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[54] **VACUUM CIRCUIT BREAKER**

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[21] Appl. No.: **105,220**

[52] **U.S. Cl.** ..... **200/144 B**

[51] **Int. Cl.** **H01n 33/66**

[58] **Field of Search** ..... 200/144 B, 166 C

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[57] **ABSTRACT**

In a vacuum circuit breaker having at least a pair of electrodes which generate an arc when detached from each other in a high vacuum tank, said electrodes are made of a copper alloy containing a low-melting-point substance and opposing contact surfaces each in the shape of a ring are placed along the periphery of the electrodes. The electrodes have about two to four grooves extending from the peripheral edge of the contact surfaces to the internal surfaces of the electrodes which are maintained detached from each other, whereby current paths in the electrodes are formed almost in parallel with the contact surfaces of the electrodes over a certain length from an arcing point in the peripheral direction at the time of ignition, thus self-driving the arc in the peripheral direction. The electrodes have on the back side thereof reinforcing materials which are mechanically strong enough to make up for the lack of the mechanical strength required for the electrodes and which are sufficiently low in electric conductivity compared with the electrode materials to such a degree so as not to allow the intensity of the magnetic field to drop to a point lower than a level required by the electrodes.

11 Claims, 9 Drawing Figures

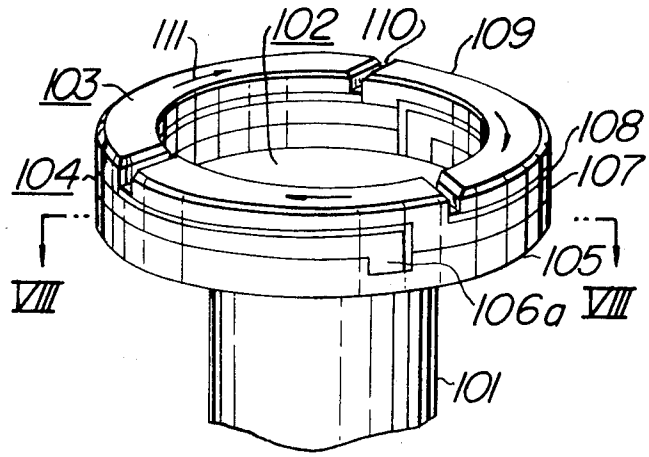
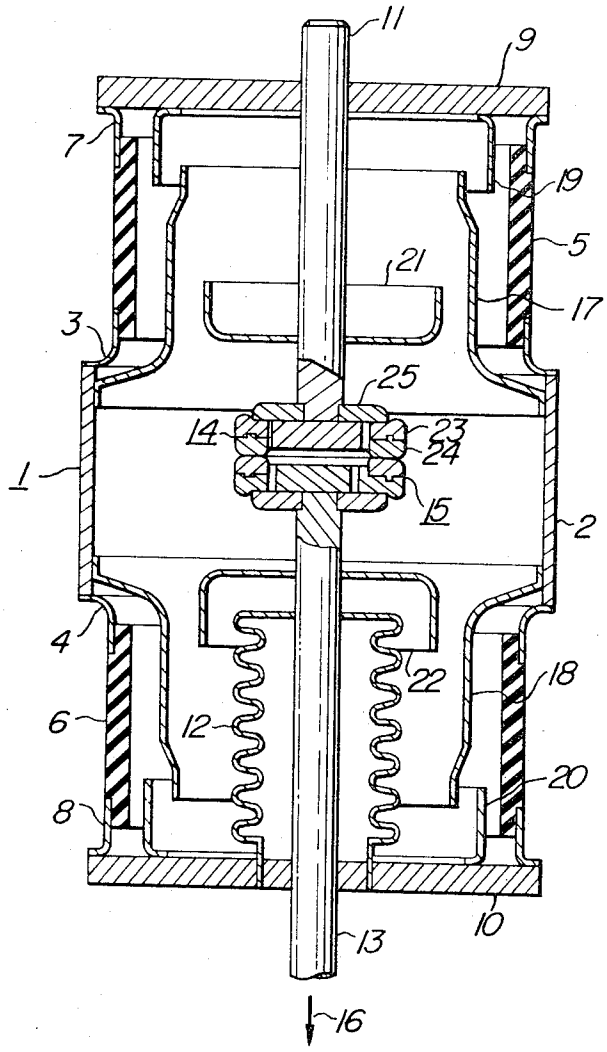


FIG. 1



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FIG. 2

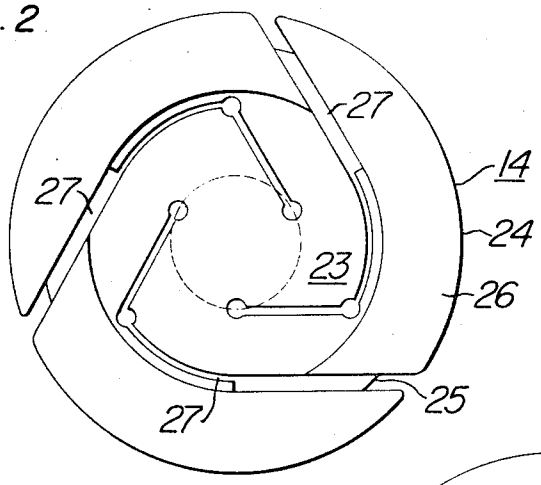


FIG. 3

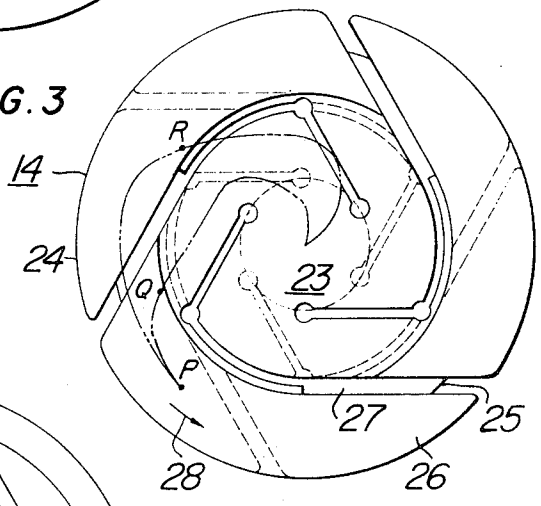
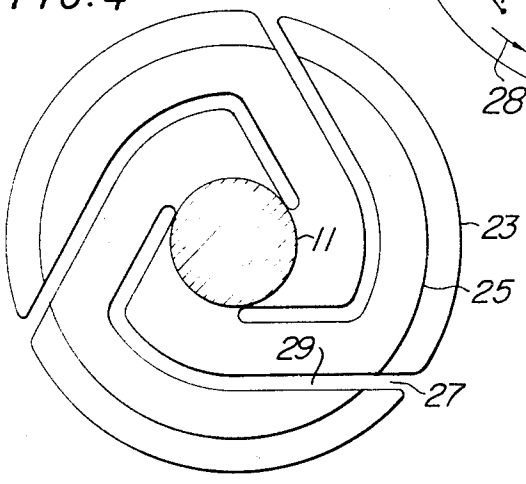


FIG. 4



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FIG. 5

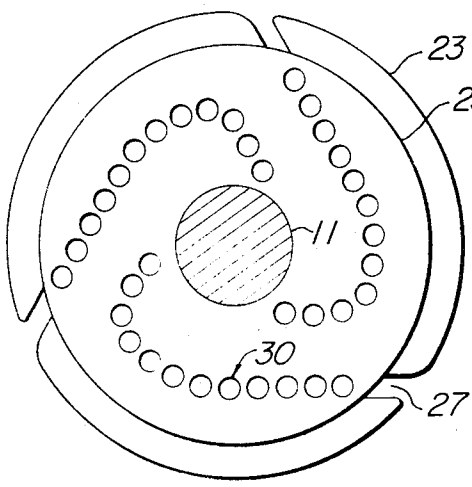


FIG. 8

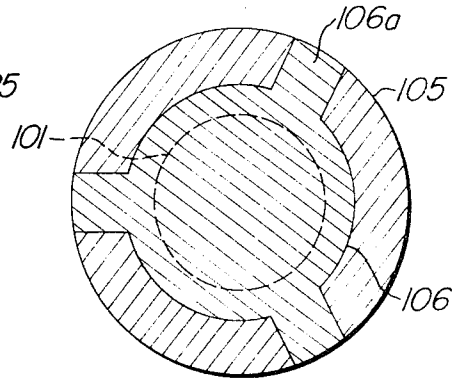


FIG. 7

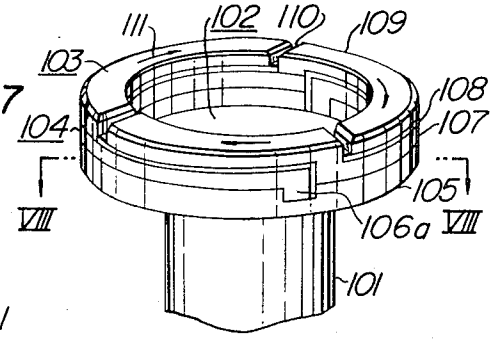


FIG. 6

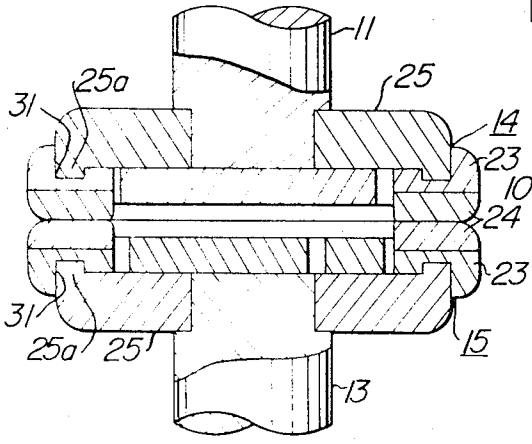
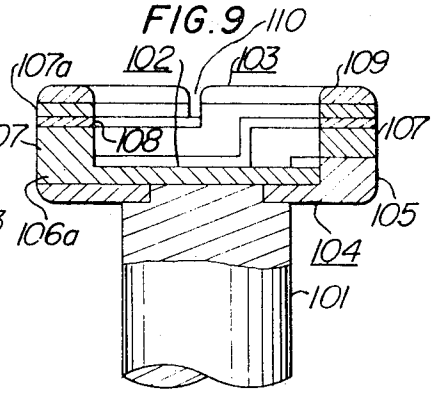


FIG. 9



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VACUUM CIRCUIT BREAKER

The present invention relates to a vacuum circuit breaker or more in particular a construction of electrodes which drives an arc generated between the electrodes, on the contact surfaces of the electrodes until the arc current becomes almost zero.

The anode temperature has a great effect on the breaking of an arc under a high vacuum of, say, 10^{-4} mmHg or less, and in the range of a large current the anode rises in temperature and melts before the cathode point spreads all over the cathode. As a result a great amount of metal vapor is supplied to the arc region, thereby sharply increasing the arc voltage. The increase in arc voltage leads to an increase in arc energy, resulting in a rapid rise in the consumption of the electrodes. According to a study by the inventors, with the increase in arc voltage, the consumption of the electrodes in terms of a unit electric charge (ampere × time) during an arcing period increases about 25 times as high as the consumption in the case of an arc due to a small current.

Consumption of the electrodes sometimes makes a breaking operation impossible because metal vaper and thermions are supplied between the electrodes even after the current becomes zero and delays the restoration of the insulation therebetween. In addition, numerous needle-like spatters are developed to reduce the dielectric strength considerably. Therefore, in order to break a large current, it is necessary that the portion which might be melted be cooled by arc driving before the current becomes zero.

For this purpose, U.S. Pat. No. 3,089,936 discloses a pipe-shaped electrode which has ring-shaped opposing contact surfaces and contacts provided with a plurality of oblique grooves extending from the contact surfaces to the pipe-shaped portion. Also, as disclosed in U.S. Pat. No. 3,185,797, disk-like electrodes have a recessed portion at their center, ring-shaped opposing contact surfaces along their periphery and ring shaped arc running surface, which detach from each other, along the periphery of the above contact surface and have a plurality of spiral grooves from the contact surfaces to the periphery of the above arc running surface.

In the former disclosure, an arc runs on the contact surfaces in the direction of their periphery, but since the grooves are oblique, the magnetic field which acts on the arc is not necessaryily strong. In the latter disclosure, an arc runs spirally in the direction of the periphery on the arc running surface and is projected beyond the radius of the electrodes. As a result, spatters which fly about due to the great heat of the arc become attached on the metal shields which are provided for preventing the creeping resistances of the surface of an insulating cylinder from being reduced by spatters attached on the surface of the insulating cylinder. Thus, not only may the metal shields be melted but no breaking operation may be made attainable due to the high arcing voltage. For this reason, in order to prevent the arc from being projected beyond the radius of the electrodes, it is necessary to consider applying a vertical magnetic field which leads to the disadvantage of the bulkiness of the conventional breaker.

Accordingly, it is an object of the present invention to provide a vacuum circuit breaker which has a sufficient driving power from the time of arc generation and is provided with electrodes which accurately drive an arc until its disappearance as a result of the current becoming almost zero.

Another object of the present invention is to provide a vacuum circuit breaker in which an arc runs between opposing contact surfaces without having any adverse effect on the breaker.

Still another object of the present invention is to provide a vacuum circuit breaker which not only meets the requirement for breaking a large current but possesses other characteristics required of a vacuum circuit breaker including resistance to fusion, high breakdown voltage and a small breaking current.

A feature of the vacuum circuit breaker according to the invention is the provision of ring-shaped opposing contact surfaces on the periphery of electrodes with a current-limiting region extending from a contacting peripheral edge to a non-contacting internal surface of the electrodes, so that a current path almost in parallel with the contact surfaces and of a certain length from an arcing point in the direction of periphery is formed in the electrodes at the time of arcing thereby to self-drive the arc in the direction of the periphery.

The above and other objects, features and advantages will be made apparent by the detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a diagram showing a longitudinal section of the vacuum circuit breaker according to the present invention;

FIG. 2 shows a front view of the electrode of the vacuum circuit breaker as shown in FIG. 1;

FIG. 3 is a diagram for explaining how an arc runs on the electrodes as shown in FIG. 2;

FIGS. 4 and 5 are plans showing different embodiments of the electrode of FIG. 2;

FIG. 6 is a diagram of a longitudinal section showing another embodiment of the electrode according to the present invention;

FIG. 7 is a perspective view of still another embodiment of the electrode;

FIG. 8 is a diagram showing a cross-section taken along the line VIII — VIII of FIG. 7; and

FIG. 9 shows a longitudinal-sectional view of the electrodes of FIG. 7.

Referring to FIG. 1, a vacuum tank 1 comprises an intermediate pipe 2 of stainless steel, ceramic cylinders 5 and 6 fixed on the ends of the intermediate pipe by the agency of connecting metals 7 and 8 respectively, and upper and lower lids 9 and 10 on which electrode holders are mounted fixedly and movably respectively.

Inside the vacuum tank 1, a fixed electrode holder 11 fixed on the upper lid 9 and a movable electrode holder 13 supported movably by a lower lid 10 through a metal bellows 12 are disposed in such a manner that the fixed and movable electrodes 14 and 15 are detachable from each other.

The vacuum tank 1 which is hermetically sealed by the metal belows maintains a high vacuum of about 10^{-8} mmHg.

The current which flows between the electrode holders 11 and 13 through the electrodes 14 and 15, while power is being fed, flows through an arc generated between the electrodes 14 and 15 as the movable electrode holder 13 is moved in the direction of the arrow 16 by a (not-shown) control system at the initial stage of cutting off the power. The current is completely cut off with the disappearance of the arc near the zero

value of the current due to the insulating and diffusing properties of a high vacuum.

In order to prevent reduction in the creeping resistance of the outer surface of the ceramic cylinder on which are attached spatters ejected from the melting electrodes due to the great heat during arcing, a direct path from between the electrodes to the ceramic cylinders **5** and **6** is blocked by means of metal shields **17, 18, 19** nd **20** fixed on the intermediate pipe **2** and the upper and lower lids **9** and **10.**

Also, shields **21** and **22** are fixed on the electrode holders **11** and **13** respectively for the purpose of preventing the spatters from being attached on the upper and lower lids **9** and **10** and bellows **12.**

It is needless to say that the above-mentioned shields are so arranged that not only the concentration of an electric field within the vacuum tank but also conduction between the lids **9** and **10** through the shields are prevented when the current is cut off.

As will be explained later, the electrodes **14** and **15** are of the same construction except that grooves on them are spiralled reversely, and they consist of a copper electrode plate **23,** an arc electrode **24** of a copper alloy containing a low-melting-point material and a reinforcing plate **25.**

Explanation will now be made of the shape of the electrodes with reference to FIGS. **1** and **2.** The ring-shaped arc electrodes **24** and disposed along the periphery of the electrodes **14** and **15** and provided with the opposing contact surfaces **26** which are brought into contact with each other. Since the arc electrodes **24** are mounted on the electrode plates **23,** the portions of the electrode plates **23** inside the rings are maintained detached from each other.

The electrodes **14** and **15** have grooves **27** which extend from the peripheral edge of the arc electrodes **24** to the internal surfaces of the electrode plates which are opposed to and detached from each other. The grooves **27** are such that the current path in the electrodes is formed by a certain length in the direction of the periphery and hence an arc is self-driven in the peripheral direction.

The electrode plates should be properly provided with three grooves **27.** If there are fewer grooves to strengthen the magnetic field, the current flow is curved and as a result a larger electromagnetic power to repel must be exerted on the electrodes with the result that a very great external force is required to bring the electrodes into contact with each other. The electromagnetic power of repellence is proportional to the square of the current value and, therefore, it is theoretically reduced in inverse proportion to the number of current paths. Actually, however, the number of current paths is limited to two or three no matter how many grooves are provided. Besides, since forces expressed in Snowdon's formula interact between currents at detached points, there is a limitation in reducing the electromagnetic power of repellence. After making a study of the number of grooves needed to create a magnetic field strong enough to cut off a large current, the inventors have found that such a magnetic field can be obtained even if the grooves are increased to four in number. The reason for the above-mentioned limitation is that a current path near an arc has too strong an effect upon the intensity of the magnetic field to reduce the intensity of the magnetic field by providing, say, only a single groove.

Because of this contradiction between the intensity of the magnetic field needed to drive an arc and the force needed to bring the electrodes into contact with each other, the grooves provided are preferably **3** in number.

Current paths in the electrodes developed at the time of ignition are illustrated in FIG. **3,** where the dotted line indicates grooves on an opposing electrode **15** for example. Assuming that an arc is generated at point P when the electrodes are separated, the arc is driven in the direction of the arrow **28** by the magnetic field produced by the currents flowing in the paths PQ and PR of electrodes **14** and **15** respectively of all the paths in the electrodes which are shown by chain-lines. The direction as shown by the arrow **28** in which the arc is driven is the same as the one of the tangential line on the periphery of the circular contact surface **26,** and because of the current paths being controlled by the reinforcing plates **25,** the magnetic field generated at the arcing point P is so strong that the arc is driven not in a radial direction but in a circle on the contact surface **26.**

An arc is liable to be ignited between the electrodes at the shortest distance when a large current flows, whereby the arc is prevented from being displaced out of the contact surfaces **26.**

The magnetic field generated at the arcing point P is strong enough to cut off a large current, because the current paths PQ and PR run parallel with each other by the reinforcing plate **25,** and the distance between the two paths is so small. The grooves on both electrodes **14** and **15** are at an angle of about **60** degrees from each other so that almost the same magnetic driving power is exerted on the arc no matter where the arc may be generated.

An arc due to a large current is difficult to drive magnetically, and the arc voltage is sharply increased when the current is increased, so that in the conventional devices it is difficult to cut off the circuit near the first zero point of the current which arrives after the ignition. In addition, the electrodes are rapidly consumed. However, according to the present invention, a strong magnetic field is uniformly applied immediately after the ignition until the arc disappears, and thereby the arc is always driven to prevent the arc voltage from being increased dependent upon the driving speed, thereby maintaining the arc voltage at a value almost equal to that due to a small current. The arc thus disappears near the first zero point of the current, minimizing the electrode consumption.

Since, as described above, no arc is displaced from the contact surfaces **26** while the arc is being driven, and also both the arc energy needed and the amount of the electrodes consumed are small, no needle spatter is produced on the electrodes after the disappearance of the arc. As a consequence, there is no marked reduction in the creeping resistance after cutting off a large current. This facilitates a mechanical process for rounding off the corners of the electrodes to prevent concentration of the electric field.

Qualifications as a vacuum circuit breaker include not only a capability of cutting off a large current but also fusion-resistance, namely, difficultly in mutual fusion of the electrodes which might be caused by the preceding discharge at the time of switching the power on, high breakdown voltage and a small breaking current, namely, a low voltage developed across the induc-

tance of the circuit due to the sudden disappearance of a current near its zero point at the time of cutting off. These requirements are met by proper selection of electrode materials, but it is generally true that those electrode materials which satisfy all the above requirements are low in mechanical strength. To compensate for this inferiority in mechanical strength, the conventional devices have a considerably complicated construction in which the contact surfaces are extended inward at the sacrifice of the useful life of the device and a shortness of the arcing time.

The electrodes of the present invention are constructed so simply that a sheet of reinforcing stainless plate **25** is attached on the back sides of electrodes **14** and **15** to solder them to the electrode holders **11** and **13** and electrode plate **23.** Although an arc due to a large current tends to be limited in space between the contact surfaces **26** of the electrodes **14** and **15,** namely, between the electrodes **24** and an arc due to a small current tends to be spread upon ignition, no ignition occurs on the reinforcing plate **25** which is higher in arc voltage than the electrode plate **23** or the arc electrodes **24** and so the arc due to a small current is limited between the electrodes. Thus, provision of the reinforcing plate **25** does not cause any deterioration of the breaking property. Also, very little current flows in the reinforcing plate **25** whose electric conductivity is as small as one twentieth to one fiftieth of that of the electrode plates **23.**

When a large current is to be cut off, however, currents which flow in opposite directions in the electrodes **14** and **15** repel each other, thereby allowing a current to flow in the reinforcing plate **25.** In this case, the current takes the shortest distance directly from the holders **11** and **13** to the arcing points of the electrodes **14** and **15** in the radial direction, so that a part of the magnetic field which otherwise might drive the arc in the radial direction is undesirably given to the arc. To overcome this difficulty, it is suggested that as shown in FIG. **4** grooves **29** be provided along the grooves **27** on the reinforcing plate **25** extending from the electrode plate **23** to the arc electrode **24** or as shown in FIG. **5** holes **30** which constitute a current-limiting region are provided to prevent the formation of a current path in the radial direction. This current-limiting region may take any form in as much as it prevents a current path from being developed in the radial direction. Neither such grooves need be the same in number as the grooves **27** in the electrode **23** and arc electrode **24.**

To increase the arc-driving speed, the distance between the parallel current paths in the electrodes **14** and **15** may be narrowed by making the electrode plate **23** thinner. In this method, however, the connecting portions of the electrode holders **11** and **13** and the electrodes **14** and **15** are weakened and the current capacity at these portions is reduced because of the presence of the recesses or the opposing internal surfaces are maintained out of contact from each other at the center of the electrodes.

To cope with this problem, channel-shaped grooves are provided along the ring-shaped contact surfaces on the back side of electrodes **23** in the manner as shown in FIG. **6,** and into these grooves the flanges **25***a* of the reinforcing plates **25** are inserted and soldered to improve the reinforcement. Thus the magnetic driving force of the electrodes **14** and **15** is increased for a further reinforcing effect.

Another embodiment of the vacuum circuit breaker according to the present invention is illustrated in FIG. **7,** where an electrode **104** comprising a disk-like portion **102** and a pipe-like portion **103** is disposed on the electrode holder **101.** The disk-like portion **102** consists of the reinforcing stainless steel plate **105** and the electrode plate **106** both soldered with the electrode holder **101** as shown in FIGS. **8** and **9.** Three protrusions **106***a* of the electrode plate **106** are integral with three conductors **107** fixed on the reinforcing plate **105.** The three conductors **107** have equal over-lapped portions and constitute a cylinder with a current-limiting material **108** of stainless steel interposed between the conductors **107,** so that a current flows in a loop through the electrode holder **101,** electrode plate **106,** protrusions **106***a* and conductors **107.** The arc electrode **109** consisting of a material containing a low-melting-point substance is fixed at a certain space **110** which is maintained on the overlapped portions **107***a.*

The opposing electrode (not shown in the drawing) is arranged with the overlapped portions of its conductors **107** disposed oppositely as shown in FIGS. **1** to **3,** with the result that an arc developed on the arc electrode **109** is powerfully self-driven in the direction of arrow **111.**

The above-mentioned electrodes seem similar in shape to the one disclosed by U.S. Pat. No. 3,089,936, but are different in that the electrodes according to the present invention have current paths almost in parallel with the contact surfaces and also the current paths are formed over a certain length from an arcing point in the peripheral direction, resulting in a very large component of the strength of the magnetic field in the peripheral direction compared with the one in the radial direction. Therefore, no arc is displaced over the radius of the periphery while being self-driven as in the case of the arc generated on the electrodes shown in FIGS. **1** and **2.** The arc is thus extinguished in the neighborhood of the zero point of the current.

Incidentally, the conductors **107** which are overlapped in two layers according to the embodiment of the drawing may be overlapped in more layers.

What is claimed is:

1. A vacuum circuit breaker having at least a pair of electrodes which are detachable from each other to generate an arc, aid electrodes comprising holding members and electrode members respectively, said electrode members including:

ring-shaped opposing contact surfaces formed at the respective ends of said holding members, thereby being capable of contacting each other;

opposing internal surfaces formed at the inside of said respective opposing contact surface nd untouchably facing each other, the inner diameters of said opposing contact surfaces being larger than the outer diameters of said holding portions , respectively; and

current-limiting regions extending from the outer peripheral edges of said contact surfaces to the inside of said opposing internal surfaces, respectively, thereby forming currents paths substantially in parallel with the contact surfaces of said electrodes over a prescribed length from an arcing point in the peripheral direction at the time of ignition, whereby the arc is self-driven in the peripheral direction.

2. A vacuum circuit breaker according to claim 1, in which said current-limiting regions are provided in the number of two to four per one electrode.

3. A vacuum circuit breaker according to claim 1, in which said current-limiting regions are formed by grooves in materials constituting the electrodes.

4. A vacuum circuit breaker according to claim 1, in which opposing contact surfaces are made of a material ontaining a low-melting-point substance , said electrode members having on the respective back sides thereof reinforcing members which are strong enough to make up for the want of the mechanical strength required of the electrodes and which are sufficiently low in electric conductivity compared with the electrode members to such a degree as not to reduce the intensity of a megnetic field to a point lower than a level required of the electrodes.

5. A vacuum circuit breaker according to claim 4, in which each of said reinforcing members has a corresponding current-limiting region along the current-limiting region provided on the electrode members, thereby preventing a current from advancing straight in the radial direction in the reinforcing members.

6. A vacuum circuit breaker according to claim 4, in which each of the electrode members has a ring-shaped recess on the back side thereof along the ring-shaped contact surface, thereby narrowing the distance between the parallel current paths formed in the opposing electrodes at the time of ignition.

7. A vacuum circuit breaker having at least a pair of electrodes which are detachable in such a manner as to generate an arc in a high vacuum tank, each of said electrodes comprising:

a holder for supporting the electrode;

a disc-shaped member including an electrode member electrically connected to said holder, the outer diameter of said electrode member being larger than the outer diameter of said holder, and a reinforcing member formed on the back side of said electrode member for mechanically reinforcing said electrode; and

a cylinder-shaped member fixed on said disc-shaped member, the inner diameter of said cylinder-shaped member being larger than the outer diameter of said holder, said cylinder-shaped member including conductor members which are electrically connected with said electrode member respectively and overlapped equally one on another sandwiching current-limiting regions therebetween respectively to form a cylinder-shaped assembly, and arc electrode members made of a substance with a low melting point provided on the upper surface of said cylinder-shaped assembly, each of said arc electrode members being fixed to said respective conductor members and being separated from the next by a current limiting groove, thereby forming current paths substantially in parallel with the contact surfaces of the electrodes over a prescribed length from an arcing point in the peripheral direction inside the electrodes at the time of ignition, whereby the arc is self-driven in the peripheral direction.

8. A vacuum circuit breaker according to claim 7, in which said reinforcing materials and said current-limiting regions are mechanically strong enough to make up for the want of the mechanical strength required by the electrodes and have sufficiently low electric conductivity compared with the electrode members to such a degree so as not to reduce the intensity of a magnetic field to a point lower than a level required of the electrodes.

9. A vacuum circuit breaker having a pair of electrodes which are detachable from each other for generating an arc therebetween, said electrodes comprising holding members and electrode members, respectively, said electrode members including:

annular opposing contact surface portions formed at the respective ends of said holding members, so as to be capable of contacting each other, the inner diameter of said opposing contact surface portions being larger than the outer diameters of said holding portions, respectively;

opposing internal surface portions spaced apart from and facing one another formed in the interior of said opposing contact surface portions and circumferentially surrounded by said annular contact surfaces ; and

means for forming current paths substantially in parallel with the contact surfaces of said contact surface portions of said electrodes over a prescribed length from the point of arcing in the peripheral direction upon ignition, including current-limiting regions extending from the outer peripheral edges of said contact surfaces to the interior of said opposing internal surface portions, respectively, whereby jhe arc is self-driven in the peripheral direction.

10. A vacuum circuit breaker according to claim 9, in which said opposing contact surface portions are made of a material containing a low-melting-point substance, said electrode members having reinforcing members on the respective back portions thereof for supplying mechanical strength to the electrodes and having a significantly lower electrical conductivity compared with the electrode members, for preventing reduction of the intensity of said magnetic field to a level lower than that required of the electrodes.

11. A vacuum circuit breaker according to claim 10, in which each of the electrode members has a ring-shaped recess on the back side thereof along the ring-shaped contact surface , thereby narrowing the distance between the parallel current paths formed in the opposing electrodes at the time of ignition.

* * * * *