

March 19, 1963

A. N. GREENWOOD ET AL

3,082,307

VACUUM TYPE CIRCUIT INTERRUPTER

Filed April 30, 1959

2 Sheets-Sheet 1

Fig. 1.

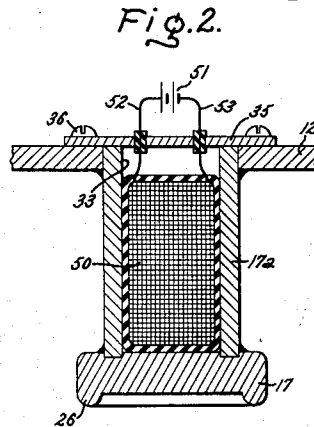
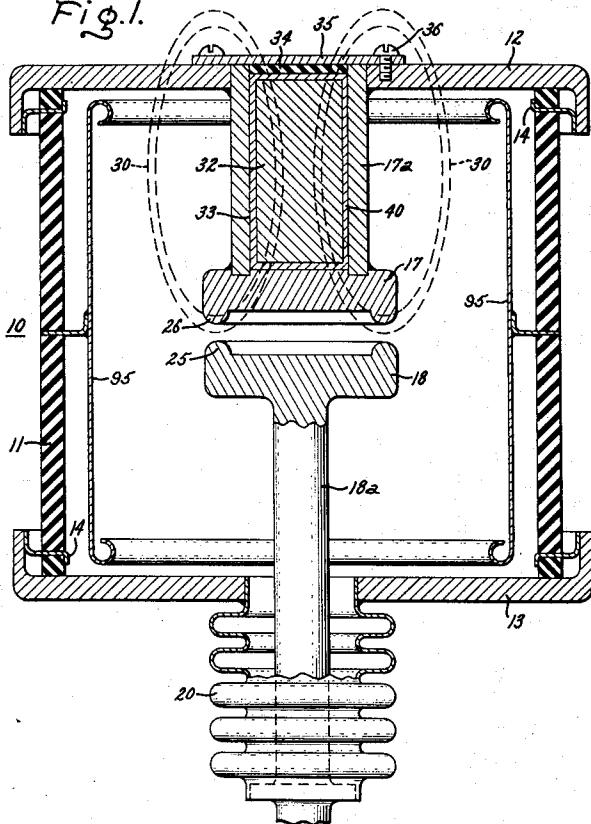


Fig. 3.

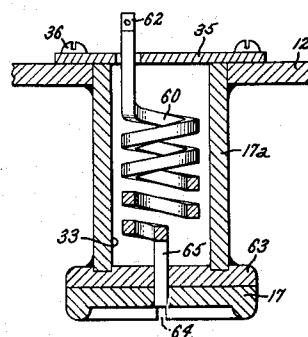


Fig. 4.

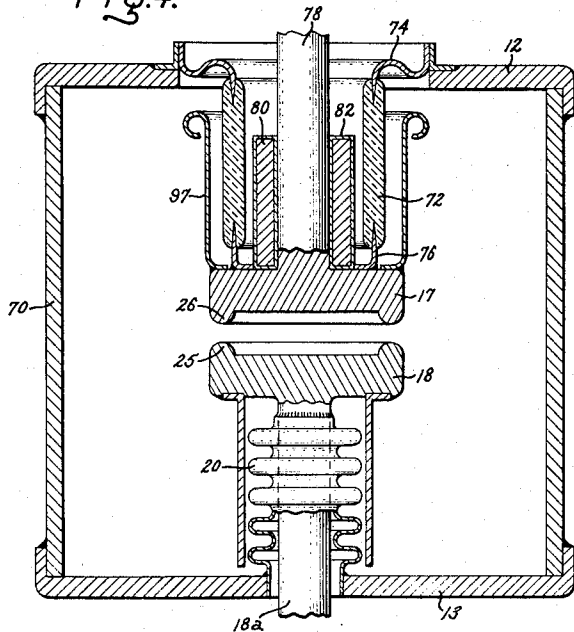
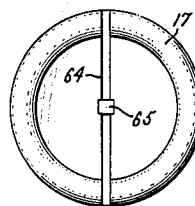


Fig. 3a.



Inventors:
Allan N. Greenwood,
Thomas H. Lee,
by *William Freedman*
Their Attorney.

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Fig. 6.

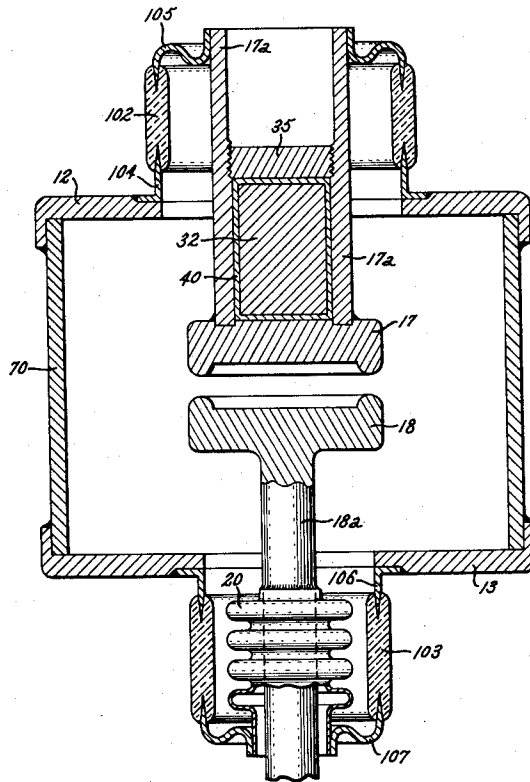
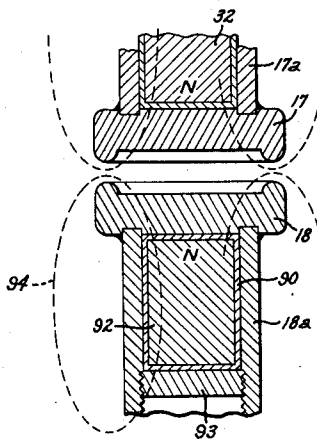


Fig. 5.



Inventors:
Allan N. Greenwood.
Thomas H. Lee,
by *William Friedman*
Their Attorney.

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3,082,307

VACUUM TYPE CIRCUIT INTERRUPTER

Allan N. Greenwood, Havertown, and Thomas H. Lee, Media, Pa., assignors to General Electric Company, a corporation of New York

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15 Claims. (Cl. 200-144)

This invention relates to an electric circuit interrupter of the vacuum-type and, more particularly, to a vacuum-type circuit interrupter that is provided with magnetic means for propelling an arc along suitable arc-running surfaces provided within the interrupter.

The usual vacuum-type circuit interrupter comprises a pair of separable contacts or electrodes disposed within an evacuated chamber. Circuit interruption is initiated by separating these contacts to establish an arc. Assuming that the circuit is an alternating current circuit, the arc maintains itself until about the time a natural current zero is reached, after which the arc is prevented from reigniting by the high dielectric strength of the vacuum.

It has been recognized heretofore that the interrupting capacity of such an interrupter can be materially increased by moving the terminals of the arc at high speed along the surfaces of the electrodes or adjacent structure. Such movement tends to minimize the amount of metallic vapors generated from the electrodes or adjacent structure by the arc and tends also to increase the degree of diffusion of the vapors that are generated. These factors enable the vacuum to recover its dielectric strength at an increased rate after a current zero and thus render the vacuum more capable of preventing reestablishment of the arc during this critical interval.

Prior schemes for moving the arc along the arc-running surfaces have relied upon a magnetic field generated either by current-carrying coils or by permanent magnets. These field-generating devices have usually been located inside the vacuum chamber of the interrupter, and this has presented numerous difficulties. One of these difficulties arises from the usual bake-out that a vacuum switch is customarily subjected to for the purpose of freeing its internal parts of adsorbed gases. Such bake-out must be carried out at relatively high temperatures, and such temperatures tend to detrimentally affect the magnetic properties of any permanent magnet located inside the vacuum chamber and tend also to weaken, through annealing, any coil structure located within the vacuum chamber. With respect to internally-located coil structures, numerous complications are involved in providing, with gas-free components, adequate electrical insulation and mechanical strength to withstand short circuit stresses.

In certain prior vacuum interrupters, the magnetic-field-producing devices have been located externally to the vacuum chamber so that it is possible to incorporate such devices after bake-out. But these prior arrangements have been relatively complicated and have not been as effective as desired because the magnetic-field-producing devices have been located relatively remote from the arcing region. Since the density of the magnetic field generally decreases as the degree of remoteness increases, such remoteness has rendered the magnetic-field-producing devices relatively inefficient in producing the desired magnetic field in the arcing region.

Accordingly, an object of our invention is to construct a vacuum circuit interrupter in such a manner that the device for producing the desired arc-propelling magnetic field, although disposed externally to the vacuum chamber of the interrupter, is located closely adjacent the arcing region thereof so as to enable the desired magnetic field to be produced in the arcing region with a high degree of efficiency.

It is a further object of our invention to drive the arc along a generally annular arc-running surface by means of a radial magnetic field derived from a field-producing device located outside the vacuum chamber but closely adjacent the arcing region.

If a permanent magnet is utilized as the field-producing device, it is a further object of our invention to preclude its being demagnetized by the currents flowing through the interrupter.

In carrying out our invention in one form, we provide an enclosed envelope defining an evacuated vacuum chamber. A pair of electrodes are located within the chamber and disposed in spaced-apart relationship during a circuit-interrupting operation so as to define an arcing gap therebetween. At least one of the electrodes has a generally annular arc-running surface along which a circuit interrupting arc can travel. The envelope contains a portion defining a recess extending from one end of the envelope to a location near the arcing gap. The recess is located outside of the vacuum chamber, and magnet means is disposed within the recess for producing a radial magnetic field traversing the arcing gap for driving arcs along the arc-running surface.

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

FIG. 1 is a side elevational view partly in section showing a vacuum-type circuit interrupter embodying one form of our invention.

FIG. 2 is a sectional view illustrating a modified form of our invention.

FIG. 3 is a sectional view illustrating another modified form of our invention.

FIG. 3a is an end view taken from the bottom of the structure shown in FIG. 3.

FIG. 4 is a side elevational view partly in section showing still another embodiment of our invention.

FIG. 5 is a sectional view illustrating still another modified form of our invention.

FIG. 6 is a side elevational view partly in section showing still another modified form of our invention.

Referring now to the interrupter of FIG. 1, there is shown a highly evacuated envelope 10 comprising a casing 11 of suitable insulating material and a pair of metallic end caps 12 and 13 closing off the ends of the casing. Suitable seals 14 are provided between the end caps and the casing to render the envelope 10 vacuum tight.

Located within the envelope 10 is a pair of separable disc-shaped contacts or electrodes 17 and 18 shown in their separated or open circuit position. The upper electrode 17 is a stationary electrode suitably secured by brazing to a tubular rod 17a of conductive material which at its upper end is united to the end cap 12 by brazing. The lower electrode 18 is a movable electrode joined to a conductive operating rod 18a which is suitably mounted for vertical movement. The operating rod 18a projects through an opening in the lower end cap 13, and a flexible metallic bellows 20 provides a seal about the rod 18a to allow for vertical movement of the rod without impairing the vacuum inside the envelope 10. As shown in FIG. 1, the bellows 20 is secured by suitable seals at its respective opposite ends to the operating rod 18a and the end cap 13.

Coupled to the lower end of the operating rod 18a, we provide suitable actuating means (not shown) which is capable of driving the electrode 18 upwardly into engagement with the electrode 17 to close the interrupter and which is also capable of returning the electrode 18 to its illustrated position so as to open the interrupter. A contact-opening operation will soon be explained in greater detail. When the interrupter is closed the circuit through the interrupter extends from the upper end cap

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12 through the tubular conductive rod 17a, the electrodes 17 and 18, and the operating rod 18a. Suitable terminals (not shown) are provided on the end cap 12 and the operating rod 18a respectively for connecting the interrupter into the power circuit which the interrupter is to control.

Each of the disclosed electrodes is of a disc-shape and has one of its major surfaces facing the other electrode. At the outer periphery of this major surface, the movable electrode 18 has an annular arc-running surface 25 which, when the interrupter is in closed position, is adapted to engage a corresponding annular arc-running surface 26 provided on the other electrode 17. When the movable contact 18 is driven downward to open the interrupter, a circuit-interrupting arc extending generally parallel to the direction of contact movement is established between the surfaces 25 and 26. As will soon be explained in greater detail, this arc is driven at high speed along the annular surfaces 25 and 26 by means of a radial magnetic field schematically indicated generally at 30. This radial magnetic field traverses the arcing gap between the surfaces 25 and 26 along substantially the entire length of the gap about the entire periphery of the contacts and interacts in a known manner with the current of the arc to produce this desired motion of the arc along the annular surfaces 25 and 26. Since the arc is initiated in a region where the radial field is already present, arc-rotation begins as soon as the arc is initiated.

For producing the above-described radial magnetic field, we rely upon a field-producing device 32 disposed within a recess 33 defined by the internal walls of the tubular contact support 17a. This device 32 is preferably a permanent magnet of cylindrical configuration having poles of opposite polarity disposed at its longitudinally opposite ends. As shown in FIG. 1, this magnet 32 is disposed radially-inward of the annular arc-running surfaces 25 and 26. The illustrated magnetic field 30 is typical of the type of field configuration which is produced by such a permanent magnet located in the position shown in FIG. 1. It is to be understood that only a few of the magnetic lines of force of the field 30 are illustrated, there being many other roughly parallel lines. These lines of force of the field 30 extend radially across the arcing gap between surfaces 25 and 26 along substantially the entire length of the gap.

It is to be noted from FIG. 1 that the recess 33 in which the permanent magnet 32 is disposed is located outside the vacuumized chamber of the interrupter. This is highly advantageous for a number of reasons. First of all, it enables the interrupter to be subjected to the usual bake-out operation without impairing the magnetic properties of the magnet. In this regard, the usual bake-out operation involves subjecting the interrupter to high temperatures during its evacuation to free the internally located surfaces of the interrupter of adsorbed gases. In assembling our interrupter, we delay incorporating the magnet 32 into the interrupter until after the bake-out operation has been completed, thus eliminating the need for subjecting the magnet to bake-out temperatures. After the bake-out operation has been completed and the interrupter suitably sealed off, we simply slip the magnet into the recess 33 and then attach suitable fastening for holding the magnet in its illustrated position. In the illustrated embodiment of our invention this fastening means comprises an insulating spacer 34 seated atop the magnet 32 and a closure disc 35 secured to the end cap 12 by suitable fasteners such as the screws 36. Incorporating the magnet 32 into the interrupter involves no impairment whatever of the vacuum since the recess 33 for receiving the magnet 32 is located outside the vacuum chamber.

Another advantage that is derived from locating the magnet outside the vacuum chamber is that the magnetic properties of the magnet can be readily checked and, in particular, can be readily checked without impairing the vacuum inside the chamber. In this regard, it is a

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simple matter to remove the closure disc 35 and withdraw the magnet 32 from its recess 33, all without opening the sealed vacuum chamber.

It is to be noted that our permanent magnet 32, though located outside the vacuum chamber, is disposed closely adjacent the arcing gap between the contacts inasmuch as it is in juxtaposition to the electrode 17. This close proximity to the arcing gap permits highly efficient use of the magnet since its magnetic field has its highest flux density in the region immediately adjacent the pole faces of the magnet. Generally speaking, the greater the distance from the pole faces, the less dense will be the magnetic field. Since the density of our field 30 approaches a near-maximum value in the region of the arcing gap, it will be highly efficient in driving the arc along the arc-running surfaces 25 and 26.

It is to be understood that the electrodes 17 and 18 and the electrode supports 17a and 18a are made of a suitable material, which in addition to being conductive, is substantially non-magnetic, e.g., copper. In view of their non-magnetic character, these parts do not interfere with attaining the desired configuration of the magnetic field 30. The electrodes 17 and 18, it should be understood are formed of materials suitably refined in vacuo in order to preclude the release of ionizable gases during arcing.

Permanent magnets tend to become demagnetized when they are traversed by magnetic flux from an external source. But in the interrupter of FIG. 1 the possibility of a harmful amount of such flux traversing the permanent magnet 32 is minimized by virtue of the magnet's location within the tubular conductor 17a and also by virtue of a copper jacket 40 completely enveloping the magnet 32. So long as the current in conductor 17a is uniformly distributed about the circumference of the conductor 17a, no substantial amount of flux will be present inside the conductor 17a in the recess 33 where the magnet is located. Any flux which does tend to enter the recess 33 for any reason, e.g., non-uniform current distribution, will induce in the copper jacket 40 currents that generate a flux opposing and thus substantially cancelling out the flux tending to enter the magnet.

The copper jacket 40 that surrounds the magnet is insulated from the tubular conductor 17a and the disc electrode 17 by a thin coating of insulation (not shown) provided about the jacket. This insulation precludes the main current through the interrupter from flowing through the jacket 40.

Although we prefer that the magnetic field producing device 32 be a permanent magnet in view of the relative simplicity of permanent magnets, it is to be understood that other types of field-producing devices may alternatively be located within the recess 33. For example, in FIG. 2 we have shown a coil 50 located within the recess 33 in a position radially-inward of the annular arc-running surface 26 and supplied with D.C. power from a suitable battery 51 through a pair of leads 52 and 53. These leads are suitably insulated from the closure 35 to prevent the coil 50 from being shorted out by the closure. Energizing the coil 50 produces a magnetic field of the same general configuration as the field 30 of FIG. 1.

As an example of another alternative device for producing the desired magnetic field, reference may be had to the embodiment of FIG. 3 which shows a coil 60 disposed within the recess 33 in a position radially-inward of the annular arc-running surface. This coil 60 is connected in series with the electrodes 17 and 18 and between the electrodes 17 and a terminal 62 of the interrupter and is therefore energized by the current which flows through the interrupter. This coil likewise produces a magnetic field of the same general configuration as that shown at 30 in FIG. 1.

If an A.C.-energized coil is utilized, as in FIG. 3, certain modifications are desirable in the interrupter structure in order to reduce the magnitude of the eddy currents

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that would otherwise be induced in those parts of the interrupter located near the coil. Such eddy currents have the undesirable effect, not only of heating the switch parts, but also of producing flux that tends to oppose and cancel out the flux produced by the coil. The modifications that we have relied upon in FIG. 3 to reduce these eddy currents to tolerable values are (1) constructing the sleeve 17a and the closure 35 of a high resistivity, low permeability metal such as stainless steel (2) providing a backing plate 63 of stainless steel for the electrode 17, and (3) slotting the electrode 17 along one or more diameters thereof.

The stainless steel parts are relied upon for sealing the vacuum chamber and thus have been made continuous or unslotted. Because of the high resistivity and low permeability of stainless steel, the eddy currents that will be induced in the stainless steel parts will be relatively low even though they do provide continuous paths for such eddy currents. The diametrically extending slot 64 in the copper electrode 17a breaks up the major circulating paths for the eddy currents induced in the copper and thus minimizes such eddy currents in the copper part. Since the copper part is not being relied upon for sealing purposes, the slot 64 does not interfere with maintenance of the required vacuum.

For connecting the coil 60 to the copper electrode 17 a short copper stud 65 brazed to the copper electrode 17 and extending in sealed relationship through the stainless steel backing plate 63 is provided. The coil 60, at its lower end, is electrically connected by suitable detachable means (not shown) to the stud 65.

As is the case with the permanent magnet 32, the coils 50 and 60 are incorporated into the interrupter structure after the interrupter has been baked-out. This eliminates any need for subjecting the coils to the usual high bake-out temperatures, and this is most advantageous because such temperatures tend to materially weaken coils such as 60 through annealing and tend to destroy the insulation of coils such as 50. The necessity that the components used for supporting and insulating the coils be gas-free is also obviated by virtue of the external location of the coils.

It is to be noted that each of the three interrupters described hereinabove has a magnetic field present in the arcing region at the time the main current flowing through the interrupter approaches and reaches zero. This follows in the interrupters of FIGS. 1 and 2 from the fact that the permanent magnet and the D.C.-energized magnet produce a magnetic field which is generally independent of the magnitude of the current flowing through the interrupter. In the interrupter of FIG. 3, the eddy currents induced in the copper electrode 17 produce enough of a phase-shift of flux relative to current to result in flux being present at current zero. We believe that the presence of a magnetic force on the arc as the current approaches zero is of considerable aid in facilitating interruption.

In the embodiment of our invention shown in FIG. 4, a cylindrical metallic casing 70, instead of an insulating casing, has been utilized as the major component of the envelope containing the vacuum chamber. As additional components of the envelope, metallic end plates 12 and 13 corresponding to similarly-designated end plates in FIG. 1 and welded to the casing 70 are provided. The movable contact-supporting rod 18a is sealed to the lower end plate 13 by means of a flexible bellows 20 in the same general manner as in FIG. 1. The movable contact 18 is carried by the rod 18a in the same manner as in FIG. 1. A suitable metallic sleeve 71 surrounding the bellows and secured to the movable contact 18 protects the bellows against possible damage by an arc.

The stationary electrode 17 is supported in FIG. 4 by means of an insulating bushing 72 which extends axially inwardly from the upper end cap 12. This bushing is sealed to the upper end cap 12 by means of a suitable

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annular seal 74 located at the upper end of the bushing and to the disc-shaped electrode 17 by means of a suitable annular seal 76 located at the lower end of the bushing 72. The bushing 72 serves to electrically isolate the upper electrode 17 from the metallic casing 70, which is at the same potential as the lower electrode 18 by virtue of its electrical connection thereto. The interrupter of FIG. 4 is connected in the power circuit which it is intended to control by means of a suitable conductive rod 78 joined to the contact 17 at the lower end of the rod 78. Suitable terminal means (not shown) are provided for electrically connecting the upper end of the rod 78 in the power circuit.

It will be apparent from FIG. 4 that the internal wall of the tubular insulating bushing 72 defines a recess which is located outside the vacuum chamber of the interrupter. Within this recess is disposed a tubular permanent magnet 80 surrounding the conductive rod 78 and located radially-inward of annular arc-running surface 26. This permanent magnet 80, which has pole faces of opposite polarity at its longitudinally opposite ends, corresponds to the magnet 32 of FIG. 1 and is capable of producing a radial magnetic field of the same general configuration as the field 30 of FIG. 1. This radial magnetic field traverses the arcing gap between the electrodes along substantially its entire length and acts to drive the arc formed between the electrodes about the annular arc-running surfaces 25 and 26 in the same manner as described relative to FIG. 1.

For minimizing demagnetization of the permanent magnet 80 by flux generated by current flowing through the interrupter, we enclose the permanent magnet 80 in a copper jacket 82. The portion of such flux which tends to enter the magnet 80 induces in the copper jacket 82 eddy currents capable of generating a counterflux that opposes the flux tending to enter the permanent magnet 80. This counterflux helps to cancel out the flux tending to enter the magnet 80 and, thus, greatly lessens the possibility that the magnetic properties of the magnet 80 will be impaired.

In designs where available space is not a controlling consideration, the rod 78 of FIG. 4 can be of a tubular construction with the magnet 80 disposed therewithin. This type of construction would further lessen the possibilities of harmful demagnetization of the magnet 80 inasmuch as flux would be excluded from the interior of such tubular conductor so long as the current in the tubular conductor remained uniformly distributed, as was explained in connection with FIG. 1.

Although the interrupter of FIG. 4 has been shown only in connection with a permanent magnet, it is to be understood that current-carrying coils, such as 50 or 60 of FIGS. 2 and 3 could instead be used for generating the desired magnetic field. In such cases, instead of the permanent magnet 80, a coil such as 50 or 60 of FIG. 2 or 3, would be disposed within the recess defined by the tubular bushing 72 of FIG. 4. If the series coil of FIG. 3 is utilized a stainless steel backing plate such as 63 shown in FIG. 3 should also be included.

If it is desired to provide a more intense magnetic field than is obtainable with a single field-producing device located adjacent the stationary contact, an additional field-producing device can be incorporated into the movable contact structure. One manner in which this can be accomplished is illustrated in FIG. 5 where the movable operating rod 18a is shown provided with a recess 90 extending along its longitudinal axis from its outer end. A permanent magnet 92 is fitted into this recess and held in place by means of a plug 93 suitably threaded into the recess. The permanent magnet 92 has its opposite poles located at its longitudinally-opposite ends and generally corresponds to the magnet 32 of FIG. 1 so that it is capable of producing a radial magnetic field 94 corresponding to the field 30 of FIG. 1. When the permanent magnet 92 is used in addition to a permanent magnet 32 as-

sociated with the stationary contact, as shown in FIG. 5, the two magnets should have their like poles opposing each other so that each magnet is capable of producing a radial magnetic field in the arcing gap region. The flux lines of each field extend from the pole face of each magnet axially toward the other magnet and then fringe radially outward across the annular arcing gap.

In the arrangement of FIG. 5, the movable electrode-supporting rod 18a defines a wall of the vacuum chamber inasmuch as the rod wall separates the vacuum chamber from the recess inside the rod. The recess of FIG. 5 is outside of the vacuum chamber and thus the magnet may be assembled therein after bake-out, in the same general manner as described relative to the upper magnet.

It is to be understood that the movable electrode structure of FIG. 5 can be used in combination with any of the stationary electrode arrangements of FIGS. 1-4 or can, if desired, be used with a stationary electrode arrangement that includes no magnet.

For protecting the insulation of a vacuum type circuit interrupter from becoming coated by metallic particles liberated from the electrodes by arcing, it is customary to provide a vapor condensing shield between the arcing gap of the interrupter and the protected insulating surfaces. Such a shield is shown in the interrupter of FIG. 1 at 95. This shield comprises a metallic tube surrounding the arcing gap and electrically isolated from both electrodes. In the interrupter of FIG. 4, the vapor condensing shield comprises a cup-shaped metallic member 97 surrounding the insulating bushing 72 and suitably supported at its lower end adjacent the stationary electrode 17. It is to be understood that all of the interrupters shown in this application are provided with suitable shields for protecting their insulation from metal-deposition even though such shield might not be shown.

In the embodiment of our invention shown in FIG. 6, identical reference numerals are used for designating parts corresponding to similar parts in the other embodiments. Referring now to FIG. 6, a metallic casing 70 similar to the metallic casing 70 of FIG. 4 has been utilized for the major portion of the vacuum enclosure. The embodiment of FIG. 6 differs from that of FIG. 4 in that both of its electrodes 17 and 18 are electrically isolated from the casing 70 instead of only one. This isolation is effected in FIG. 6 by means of glass or ceramic insulating bushings 102 and 103 disposed electrically between the casing 70 and the electrodes. More specifically, the upper bushing 102 is mounted on the end cap 12 by means of suitable sealing structure 104 disposed between the lower end of the bushing and the end cap 12, whereas the electrode 17 is mounted from the upper end of the bushing 102 by means of suitable sealing structure 105 disposed between the bushing and the electrode-supporting rod 17a. The lower bushing 103 is mounted on the lower end cap 13 by means of suitable sealing structure 106 disposed between the bushing 103 and the end cap 13, and a seal 107 is suitably joined at its opposite ends to the bushing 103 and the bellows 20 surrounding the movable operating rod 18a. A magnet 32 corresponding to the similarly-designated magnet of FIG. 1 and enclosed by a copper jacket 40 is mounted within the recess formed in the tubular rod 17a and produces a magnetic field corresponding to the field 30 of FIG. 1. A suitable closure 35 threaded into the tubular rod 17a holds the magnet 32 in position.

The upper bushing 102 of FIG. 6 differs from the bushing 72 of FIG. 4 in that it is loaded in compression rather than tension by atmospheric pressure acting on the stationary electrode structure 17, 17a. This is advantageous in view of the relatively great strength of glass or ceramic materials in compression as compared to tension.

Isolating the casing 70 from both electrodes is advantageous in that such isolation enables a symmetrical

electric field to be obtained in the arcing gap region, i.e., a field which is generally symmetrical with respect to a reference plane which bisects the arcing gap between the open contacts and extends perpendicular to the longitudinal axes of the contact rods. This symmetry follows from the fact that the metallic casing 70 is at approximately a mid-potential with respect to the electrodes and remains as such mid-potential despite the condensation of arc-liberated contact-material vapors on the casing 70. Thus a mid-potential line would approximately bisect the arcing gap and half of the voltage would be distributed over one half of the arcing gap with the other half of the voltage distributed over the other half of the arcing gap.

With regard to this general matter, it should be noted that arcing gaps in general have a lower breakdown strength when subject to voltage of one polarity than when subjected to voltage of an opposite polarity. The more asymmetrical is the electrical field in the region of the gap, the more pronounced is this polarity effect. By providing a symmetrical field, this polarity effect is minimized. As a result, the interrupter of FIG. 6 is especially suited to preventing any unduly prolonged arcing that could result from low dielectric strength during alternate half cycles.

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

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

1. A vacuum-type circuit interrupter comprising an enclosed envelope defining an evacuated vacuum chamber, a pair of relatively-movable electrodes located within said chamber and having generally aligned annular arc-running surfaces, means for moving one of said electrodes relative to the other of said electrodes to provide an arcing gap between said arc-running surfaces across which circuit-interrupting arcs extending generally parallel to the direction of electrode movement are developed, said arcs being maintained in said generally parallel relationship until extinguished, said envelope containing a portion defining a recess extending from one end of said envelope to a location near said arcing gap, said recess being located outside of said vacuum chamber, and magnet means disposed within said recess in a position disposed radially-inward of said annular arc-running surfaces for producing a magnetic field traversing said arcing gap in a generally radial direction along substantially the entire length of said gap and about substantially the entire periphery of said arc-running surface for driving arcs along said arc-running surface, the arc-initiating portions of said electrodes being so disposed that said arcs are initiated in a region traversed in a radial direction by said magnetic field.

2. The interrupter of claim 1 in which said magnet means comprises a permanent magnet extending longitudinally of said recess, and means for substantially reducing the amount of externally generated flux penetrating said magnet comprising a jacket of highly-conductive, substantially non-magnetic metal enclosing said permanent magnet both at its ends and about its periphery.

3. The interrupter of claim 1 in which said magnet means comprises a current-carrying coil connected in series with said electrodes and located closer to one electrode than the other electrode, the walls of said recess being constructed of a high resistivity non-magnetic material, said electrode that is closer to said coil being constructed of a higher conductivity metal than the material of said recess wall and being slotted in such a manner

as to break up the major paths for eddy currents induced in said closer electrode.

4. A vacuum-type circuit interrupter comprising an enclosed envelope defining an evacuated vacuum chamber, a pair of relatively movable electrodes located within said chamber and having generally aligned annular arc-running surfaces, means for moving one of said electrodes relative to the other of said electrodes to provide an arcing gap between said arc-running surfaces across which circuit interrupting arcs extending generally parallel to the direction of electrode movement are developed, said arcs being maintained in said generally parallel relationship until extinguished, a conductive support for one of said electrodes projecting into said vacuum chamber and containing a recess extending along the length of said support to a location near said arcing gap, said recess being located outside of said vacuum chamber, and magnet means disposed within said recess in a location disposed radially-inward of said annular arc-running surfaces for producing a radial magnetic field traversing said arcing gap along substantially the entire length of said gap for driving arcs along said arc-running surface, the arc-initiating portions of said electrodes being so disposed that said arcs are initiated in a region traversed in a radial direction by said magnetic field.

5. The interrupter of claim 4 in which said magnet means comprises a permanent magnet extending longitudinally of said recess, and means for substantially reducing the amount of externally generated flux penetrating said magnet comprising a jacket of highly-conductive, substantially non-magnetic material enclosing said permanent magnet.

6. The interrupter of claim 4 in which said envelope comprises a metallic casing and a tubular insulating bushing disposed between said metallic casing and said conductive support for mounting said conductive support on said casing, and means for mounting said bushing on said casing in such a position that fluid pressure external to said envelope loads said bushing in compression.

7. In a vacuum-type circuit interrupter, an enclosed envelope defining a vacuum chamber, said envelope comprising a casing of conductive material and a tubular insulating bushing projecting into said vacuum chamber, a pair of relatively movable electrodes located within said chamber and having generally aligned annular arc-running surfaces, means for moving one of said electrodes relative to the other of said electrodes to provide an arcing gap between said arc-running surfaces across which circuit-interrupting arcs extending generally parallel to the direction of electrode movement are developed, said arcs being maintained in said generally parallel relationship until extinguished, means including said tubular bushing for defining internally of said bushing a recess extending longitudinally of said bushing to a location near said arcing gap, said recess being located outside of said vacuum chamber, and magnet means disposed within said recess in a location disposed radially-inward of said annular arc-running surfaces for producing a radial magnetic field traversing said arcing gap along substantially the entire length of said gap for driving arcs along said arc-running surface, the arc-initiating portions of said electrodes being so disposed that said arcs are initiated in a region traversed in a radial direction by said magnetic field.

8. The interrupter of claim 7 in which current is conducted to and from one of said electrodes by means of a conductor extending through the bore of said tubular bushing.

9. The interrupter of claim 7 in which current is conducted to and from one of said electrodes by means of a conductor extending through the bore of said tubular insulating bushing, and in which said magnet means comprises a generally cylindrical permanent magnet disposed about said conductor.

10. The interrupter of claim 9 in combination with means for substantially reducing the amount of externally generated flux penetrating said magnet comprising a jacket of highly conductive substantially non-magnetic material enclosing said permanent magnet both at its ends and about its periphery.

11. A vacuum-type circuit interrupter comprising an enclosed envelope defining an evacuated vacuum chamber, a pair of relatively movable electrodes located within said chamber and having generally aligned annular arc-running surfaces, means for moving one of said electrodes relative to the other of said electrodes to provide an arcing gap between said arc-running surfaces across which circuit interrupting arcs extending generally parallel to the direction of electrode movement are developed, said arcs being maintained in said generally parallel relationship until extinguished, said envelope containing re-entrant portions defining recesses extending from opposite ends of said envelope to locations near said arcing gap, both of said recesses being located outside of said vacuum chamber, and magnet means disposed within each of said recesses in a location disposed radially-inward of said annular arc-running surfaces for producing a radial magnetic field traversing said arcing gap along substantially the entire length of said gap for driving arcs along said arc-running surface, the arc-initiating portions of said electrodes being so disposed that said arcs are initiated in a region traversed in a radial direction by said magnetic field.

12. A vacuum-type circuit interrupter comprising an evacuated chamber, a pair of relatively movable electrodes located within said chamber and having generally aligned annular arc-running surfaces, means for moving one of said electrodes relative to the other of said electrodes to provide an arcing gap between said arc-running surfaces across which circuit interrupting arcs extending generally parallel to the direction of electrode movement are developed said arcs being maintained in said generally parallel relationship until extinguished, a conductive support for each of said electrodes projecting into said vacuum chamber and each containing a recess extending along the length of said support to a location near said arcing gap, both of said recesses being located outside of said vacuum chamber, and magnet means disposed within each of said recesses in a location radially-inward of said annular arc-running surfaces for producing a radial magnetic field traversing said arcing gap along substantially the entire length of said gap for driving arcs along said arc-running surface, the arc-initiating portions of said electrodes being so disposed that said arcs are initiated in a region traversed in a radial direction by said magnetic field.

13. A vacuum-type circuit interrupter comprising an enclosed envelope defining an evacuated vacuum chamber, a pair of relatively movable electrodes located within said chamber having arc-running surfaces, means for moving one of said electrodes relative to the other of said electrodes to provide an arcing gap between said arc-running surfaces across which circuit interrupting arcs extending generally parallel to the direction of electrode movement are developed, said arcs being maintained in said generally parallel relationship until extinguished, a conductive support for one of said electrodes projecting into said vacuum chamber and containing a recess extending along the length of said support to a location near said arcing gap, said recess being located outside of said vacuum chamber, and magnet means disposed within said recess for producing a radial magnetic field traversing said arcing gap along substantially the entire length of said gap for driving arcs along said arc-running surface, the arc-initiating portions of said electrodes being so disposed that said arcs are initiated in a region traversed by said magnetic field.

14. The interrupter of claim 13 in which said magnet

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means comprises a permanent magnet extending longitudinally of said recess, and means for substantially reducing the amount of externally generated flux penetrating said magnet comprising a jacket of highly-conductive, substantially non-magnetic material enclosing said permanent magnet.

15. The interrupter of claim 13 in which said magnet means comprises a current-carrying coil connected in series with said electrodes and located closer to one electrode than the other electrode, the walls of said recess being constructed of a high resistivity non-magnetic material, said electrode that is closer to said coil being constructed of a higher conductivity metal than the material of said recess wall and being slotted in such a manner as to break up the major paths for eddy currents induced in said closer electrode.

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