Dec. 19, 1961 J. D. COBINE ET AL 3,014,108

VACUUM SWITCH

Filed Jan. 2, 1959

Fig. 1.

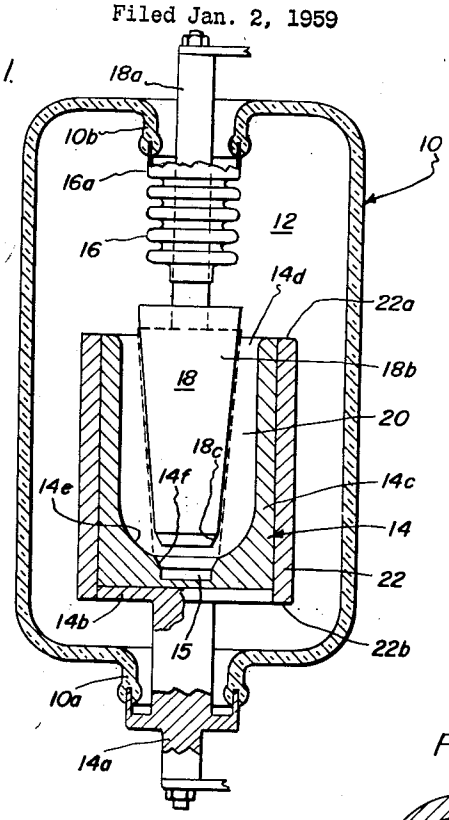


Fig. 2.

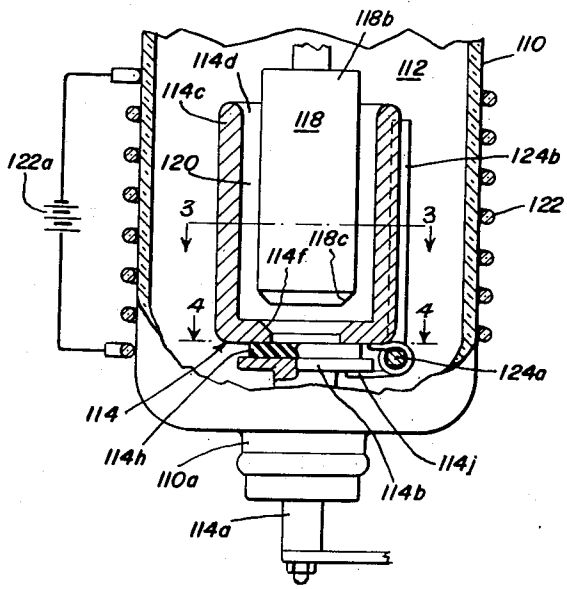


Fig. 3.

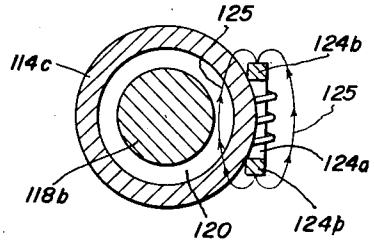
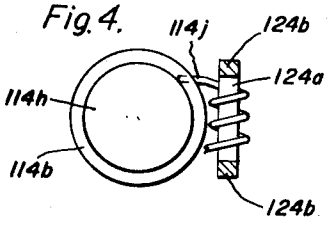


Fig. 4.



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VACUUM SWITCH

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Our invention relates to an improved alternating current vacuum switch mechanism of the type in which a circuit-interrupting arc is maintained by vaporized electrode material substantially until current zero before interruption.

In vacuum type switches an envelop, partially or totally fabricated from glass or other suitable insulating material, forms a vacuum cavity in which a pair of relatively movable electrodes are located. In one position of the electrodes, direct conducting contact is made between them to carry the current flow of the circuit to which the switch is connected. In a second, circuit-opening position, the electrodes are spaced and no current flows therebetween. It is the function of the switch to transfer from the circuit-making to the circuit-opened condition in reliable fashion, assuring that the current flow is promptly interrupted and yet no excessive overvoltages occur in the connected circuits. To this end, it is important that the current flow be maintained in the switch until the alternating current would otherwise fall to zero, thus assuring that there is no sudden current interruption to create circuit overvoltages. In addition, long life and reliability demand that the unit be so constructed that the electrode erosion associated with arcing action is minimized and the deposit of conducting electrode material on the inside walls is likewise minimized.

In the switch herein described, the electrodes are in the form of telescoping members that define an elongated annular space. In the contact-making position of the electrodes, a current-carrying path is defined between the end of the inner electrode and the base of the cavity of the outer electrode. When the inner electrode is withdrawn, an arc is struck at or near the surface of initial contact. The unit is operative to cause the arc so struck to travel toward the open end of the cavity under the influence of variations in the length of the arcing gap, and magnetic interaction. This arc travel, coupled with the influence of a magnetic field in the longitudinal direction of the annular space thereupon, gives rise to a spiral path of movement of the arc away from the base of the cavity and towards the opening thereof. The length of the cavity is sufficient to assure that at least a substantial portion of the time to the next occurring current zero passes before the arc reaches the opening of the cavity. Since the arc is in continuous movement and traverses a substantial portion of the electrode area, the eroding effect of the arc on the electrode material is distributed and the electrodes have long life before undue eroding occurs. Moreover, the space in which the electrode material is vaporized is largely surrounded by the electrodes themselves (at least during most of the arcing period) and relatively small quantities of vaporized electrode material escape into the vacuum space proper to deposit on the insulating walls thereof.

It is therefore an object of the present invention to provide an improved vacuum-type switch in which relatively movable telescoping members coact with a magnetic field to impart a spiral movement of the arc until current zero is reached.

Another object of the present invention is to provide an improved alternating current vacuum switch mechanism in which relatively movable telescoping members define an annular space of decreasing arc resistance as

the arc moves away from the initial contact-making portions, and a magnetic field imparts spiral movement to the arc as it travels in response to the decreasing arc resistance.

It is still another object of the present invention to provide an improved alternating current vacuum switch construction in which the action of axial and circumferential magnetic fields serves to impart a spiral-like travel to the arc upon circuit opening.

Yet another object of the present invention is to provide an improved vacuum switch mechanism for use in alternating current circuits and having features of construction, combination and arrangement that provide a simple, readily manufactured, highly reliable, long life unit that is especially suitable for use in commercial circuit breaking or switching applications and can be modified to varying forms to accommodate a wide range of circuit conditions and performance requirements.

The novel features which we believe to be characteristic of our invention are set forth with particularity in the appended claims. Our invention itself, however, together with further objects and advantages thereof, will best be understood by reference to the following description taken in conjunction with the accompanying drawing in which:

FIG. 1 is an axial cross-sectional view with parts in elevation of a switch constructed in accordance with the present invention and incorporating permanent magnet elements within the vacuum space;

FIG. 2 is a fragmentary view generally like FIG. 1 but showing a switch with solenoid means to create a circumferential magnetic field; and

FIGS. 3 and 4 are fragmentary enlarged cross-sectional views through axes **3—3** and **4—4**, of FIG. 2, respectively.

Referring now to FIG. 1, there is provided an insulating envelop **10** defining a generally cylindrical vacuum space indicated at **12**. The envelop **10** may, for example, be of glass, although other vacuum tight insulating materials may be used. At end **10***a* the envelop **10** receives the shank portion **14***a* of the outer and fixed electrode **14**. The shank portion **14***a* of electrode **14** is of a conducting material that adheres tightly to the envelop material to prevent passage of air therebetween, at least in the portions embedded in the envelop **10**. At the opposite end **10***b*, the envelop **10** embeds the peripheral portion of the disk **16***a* of the bellows **16**, again forming a vacuum-tight joint. Bellows **16** forms a relatively movable but vacuum-tight structure embracing the shank portion **18***a* of the movable electrode **18**.

Suitable means (not shown) are provided to move the movable electrode **18** between the dotted line position of FIG. 1 and the solid line position shown. In the former position, the electrodes **14** and **18** are in physical contact at seating faces **18***c* and **14***f* to conduct current. In the latter position they are spaced and, after current interruption, are electrically disconnected.

The shank **14***a* of the fixed electrode **14** forms a conducting supporting disk **14***b* within the vacuum space **12**. This disk is affixed to and receives the arcing electrode portion, indicated at **14***c*. As shown, this portion is of cup shaped conformation having a cylindrical outer surface and an elongated longitudinal cavity. This cavity has an opening **14***d* through which electrode **18** extends, and a base **14***e* opposite the opening. A secondary cavity **15** is located centrally of the base **14***e* to assure arc travel toward the opening **14***d* as hereinafter described. The lip **14***f* defined by secondary cavity **15** and the base **14***e* is beveled to form a contact-making annular seat as hereinafter described.

As shown, the inner electrode **18** is telescopically positioned within the cavity formed by electrode **14**. Elec-

trode **18** includes an elongated truncated conical head portion **18***b* affixed to the shank portion **18***a* and is of smaller diameter toward the base **14***e* of the cavity in electrode **14**. The head portion of electrode **18** is beveled at **18***c* to make contact with the lip **14***f* of electrode **14**, as shown.

The cavity of the electrode **14** and the head portion **18***b* of the electrode **18** coact to define an elongated annular space **20**. In the structure shown, this space is of circular cross-section and increases in cross-sectional area toward base **14***e* of the cavity in electrode **14**. As hereinafter described, the arc associated with current interruption spirally travels within this space and away from the base **14***e* until current zero is reached.

The cup portion **14***c* of the electrode **14** receives the jacket **22**. This is of permanent magnet material, such as an Alnico alloy and is magnetized to produce one permanent magnet pole at end **22***a* and a magnet pole of opposite polarity at end **22***b*. The resulting magnetic field at the annular space **20** is in the longitudinal direction of this space, that is, in the direction of the axis of symmetry of the cavity of electrode **14** and the head portion **18***b* of the electrode **18**, and the direction of movement of electrode **18**.

If desired, the magnet sleeve **22** may be replaced by a solenoid or a series of bar magnets distributed about the periphery of the electrode portion **14***c* and forming elements of the cylinder defined thereby. Chamber **12** within envelop **10** is maintained at a pressure of less than 10^{-4} mm. of mercury in order that gaseous ionization be substantially absent.

The headed portion **18***b* of electrode **18** and the cavity-defining portion **14***c* of electrode **14** are of a conducting material capable of vaporization to form conducting ions within the space **20**. Materials of this kind are described in Lee and Cobine patent application S.N. 750,784, filed July 24, 1958, assigned to the same assignee as the present invention. Suitable materials include tin, antimony, lead, zinc, manganese, bismuth, and alloys thereof, as well as conventional electrode materials such as copper, aluminum, and alloys thereof. These materials are refined in vacuo to remove all sorbed gases as set forth in the Lee and Cobine application to prevent the pressure within the switch from rising with repeated use.

The cavity formed by electrode **14** and the headed portion **18***b* of electrode **18** are so shaped that they define an annular space **20** having decreased arc resistance as the opening **14***d* is approached. This makes the arc formed at or near the contact-making surfaces **14***f* and **18***c* travel away from these surfaces and towards the opening **14***d*. The actual rate of arc movement is determined by the magnetic, electrical, and thermal effects of the arc current itself and by its interaction with the longitudinal magnetic field within the electrodes and the annular space **20**. In general, the arc tends to seek the shortest span across the annular gap **20** and for this reason the necessary motion is readily controlled by forming the head portion **18***b* of movable electrode **18** with a conical shape as shown. Alternatively, electrode **18** may be cylindrical and electrode **14** conical toward end **14***d*. Normally this is sufficient to cause the requisite axial arc travel. As hereinafter described in more detail with respect to the construction of FIG. 2, this motion may also be accomplished by the coaction of the longitudinal magnetic field within the annular space **20** and a circumferential magnetic field therein independently of electrode shape. The essential point is that the arc, initiated at the contact-making surfaces **18***c* and **14***f*, tends to travel away from these surfaces in a spiral-like motion.

The longitudinal magnetic field within the annular space **20** causes the arc to rotate therein. This is due to the coaction of the magnetic field of the radial arc itself, and the longitudinal magnetic field. The arc tends to move in a direction at right angles both to the magnetic field and its own direction of current flow, thus giving a circumferential direction of movement and rotation of the arc about the space **20**.

It will be observed that the combined effect of the rotation of the arc under the influence of the longitudinal magnetic field in annular space **20** and the movement of the arc towards the opening **14***d* is that of imparting a spiral motion to the arc as it travels away from the contact-making surfaces **14***f* and **18***c*. The length of the annular space **20** is preferably made sufficient to assure that a current zero is reached before the arc reaches the opening **14***d*. For example, in a sixty cycle circuit, the length of the space **20** is made greater than the longitudinal distance the arc travels in $\frac{1}{120}$ second, thus assuring that regardless of the instant the electrodes separate, there is ample time for the current zero to be reached before the arc reaches the opening **14***d*. This distance, of course depends upon the current interrupted and the value of the longitudinal magnetic field and may readily be determined.

It is not essential, however, that the axial length of annular space **20** absolutely exceed the longitudinal distance the arc travels in half the alternating current cycle. The statistical prospect of requiring a full half cycle to the next occurring current zero is small and the arc current falls as it approaches the zero point. For these reasons adequate performance may be achieved by relying upon the arc rotating about opening **14***g* to carry the low current existing just prior to the current zero condition when the electrodes separate under the most adverse condition. The cavity **20** may thus be made somewhat shorter than that corresponding to one half cycle.

It will be noted that the arc is in continuous motion during the circuit-opening operation and that such motion is symmetrical about the axis of the electrodes. Consequently the erosion associated with the arc action on the electrode materials is distributed over considerable electrode area and at no time does the arc dwell at particular electrode points to heat and erode the same excessively. Moreover, since the arc is initiated at the base end of the cavity, the vaporized electrode material is located deep in the cavity and tends to deposit on the electrodes themselves rather than escaping through opening **14***d* to condense on the insulating walls of the envelop **10**. If desired, the axial length of the annular space **20** may be increased over the length dictated by considerations of the alternating current frequency and longitudinal magnetic field strength to decrease the amount of vaporized electrode material so escaping. Alternatively, one or more disk-shaped baffles, or their functional equivalents, may be located near opening **14***d* to prevent loss of electrode material by evaporation and condensation.

FIGS. 2–4 are fragmentary views of a vacuum switch constructed in accordance with an alternative embodiment of the present invention. In this construction, the evacuated envelop **110** defines vacuum space **112** and at its end **110***a* embeds and supports the shank **114***a* of the fixed electrode unit indicated generally at **11***e*. This unit includes an electrode proper, indicated at **114***c*, which defines a cavity having end opening **114***d*. An insulated spacer disk **114***d* supports the electrode proper from the support disk **114***b* and is attached to electrode proper **114***c* and support disk **114***b* by suitable insulated bolts or other fasteners (not shown). A suitable conductor **114***j* is affixed and electrically connected to disk **114***b*. This conductor makes at least one turn about the magnetic core **124***a* as shown, and is affixed and electrically connected to the base end of the electrode proper **114***c*. The magnetic core **124***a* has two upstanding arms **124***b* extending up the side of the fixed electrode **114***c* as shown.

The movable electrode **118** has a head portion **118***b* similar to **18***b*, FIG. 1, but with a cylindrical lateral surface. This head portion has a beveled end at **118***c* which coacts with the beveled seat **114***f* of the fixed

electrode **114** to form an annular contact surface for normal current conduction. A solenoid winding **122** is wrapped about the envelop **110** in the region of the annular space defined by electrodes **114** and **118** and is energized by suitable D.-C. voltage source **122***a* to provide a longitudinal magnetic field in the annular space **120**.

In the apparatus of FIGS. 2–4, the current flow between the electrodes **114** and **118** passes from the shank **114***a* to the disk **114***b* and thence by conductor **114***j* about the core **124***a*. This current creates a magnetomotive force along the length of core portion **124***a* and accordingly a magnetic field between the arms **124***b*. This field fringes as shown by the dashed line **125**, FIG. 3, to extend in a generally circumferential direction across one side of the annular space **120**. The field is accordingly located substantially along one element of the cylinder defined by the annular space **120**. When the arc is within this field, it is driven by magnetic action towards the opening **114***d* of the cavity in electrode **114***c*. Since the direction of the field is determined by the direction of the current flow through conductor **114***j*, the proper relationship between field orientation and current flow always exists to drive the arc towards opening **114***d*. The effect of this field (exemplified by line **125**, FIG. 3) is to shift the arc some axial distance towards the opening **114***d* on every full circumferential movement about the annular space **120**. The field of the winding **122** accordingly coacts with the circumferentially directed field (exemplified by line **125**, FIG. 3) to impart spiral-like movement of the arc and thereby achieve action similar to that achieved solely through the electrode configuration in the embodiment of FIG. 1. This electrode configuration may also be used in this embodiment to fortify the magnetic action described herein.

The core **124** is preferably made of a laminated magnetic material. Silicon steel may, for example, be used. The conductor **114***j* and the core **124** are separated by suitable insulating barrier (not shown) at their areas of contact to assure full current flow through this conductor. If desired, the electrodes **114** and **118** may be provided with auxiliary contact-making faces to bypass the conductor **114***j* under normal current carrying conditions.

In FIG. 2, it will be noted that the magnet **22** is located wholly within the vacuum space and does not extend closer to movable electrode **18** than the fixed electrode proper, **14***c*. Since the vacuum space is a highly effective insulating medium, this location of the magnet has the advantage of maintaining the full insulating path defined between the electrodes **14** and **18** by the outside face of the envelop **10**. If desired, the winding **122**, FIG. 2, may have a greater radius than is shown in FIG. 2 to space the conductor thereof some distance from the outer face of the envelop **10** and thereby minimize the chance of external breakdown along the outside face of envelop **10** and through the winding.

In the appended claims the electrodes are referred to as being so shaped that in the circuit-opening position the arc travels towards the mouth of the cavity in the outer electrode. The actual arc movement is primarily the result of magnetic effects and interactions. By this language we intend to define a shape of the electrodes such that in conjunction with these effects the arc moves as described. In various constructions, of course, the actual shapes of the electrodes may be different from those in other applications due to the variations in these magnetic effects.

While we have shown and described specific embodiments of the present invention it will, of course, be understood that various modifications and alternative constructions may be made without departing from the true spirit and scope thereof. We therefore intend by the appended claims to cover all such modifications and alternative constructions as fall within their true spirit and scope.

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

1. An alternating current vacuum switch mechanism of the type in which a circuit-interrupting arc is maintained by vaporized electrode material substantially to current zero before interruption, the mechanism comprising in combination: means defining a vacuum space; a first electrode extending through said means to define a first circuit terminal outside said space, said electrode defining a cavity having a base and an open end within said space, the base of said cavity having a centrally located secondary bore defining an annular lip at its junction with the base; a second electrode telescopically received in said cavity and extending outside said space to define a second circuit terminal outside said space, said second electrode forming an elongated annular space in relation to said first electrode; said electrodes being movable relative to each other in the longitudinal direction of the annular space, said movement being between a first position in which the electrodes are in contact-making relationship at said lip and a second position in which said electrodes are out of contact, the electrodes being so shaped that the radial distance between the electrodes is greater at the closed end of said annular cavity than at the open end thereof so that when the electrodes are in said second position an arc therebetween travels towards the open end of said cavity; and means creating a magnetic field longitudinal of said annular space, the length of said annular space being greater than at least a major portion of the distance the arc travels in a half cycle, whereby as the electrodes are moved from the first position to the second position the arc is struck at said lip and spirals towards the open end of the cavity until substantially current zero.

2. An alternating current vacuum switch mechanism of the type in which a circuit-interrupting arc is maintained by vaporized electrode material substantially to current zero before interruption, the mechanism comprising in combination: means defining a vacuum space; a first electrode extending through said means to define a first circuit terminal outside said space, said electrode defining a cavity having a base and an open end with said space; a second electrode telescopically received in said cavity and extending outside said space to define a second circuit terminal outside said space, said second electrode forming a longitudinal annular space in relation to said first electrode; said electrodes being movable relative to each other in the longitudinal direction of said annular space, said movement being between a first position in which the electrodes are in contact-making relationship at the base of said cavity and a second position in which said electrodes are out of contact, the electrodes being so shaped that the radial distance between said electrodes is smaller at the open end of said cavity than at the closed end thereof so that when the electrodes are in said second position an arc therebetween travels towards the open end of said cavity; the length of said annular space being greater than at least a major portion of the distance the arc travels in a half cycle, and means creating a magnetic field lengthwise of said annular space, whereby as the electrodes are moved from the first position to the second position the arc is struck at the base of the cavity and spirals towards the open end thereof until substantially current zero.

3. An alternating current vacuum switch mechanism of the type in which a circuit-interrupting arc is maintained by vaporized electrode materials substantially to current zero before interruption, the mechanism comprising in combination: means defining a vacuum space; a first electrode having at least portions within said space and of elongated cup shaped conformation with a cylindrical outer wall and an elongated cavity having a base; a second electrode telescopically received in said cavity and defining a longitudinal annular space in rela-

tion to the first electrode; said electrodes being movable relative to each other in the longitudinal direction of the annular space, said movement being between a first position in which the electrodes are in contact-making relationship at the base of said cavity and a second position in which said electrodes are out of contact, the electrodes being so shaped that the radial distance between said electrodes is greater at the open end of said cavity than at the closed end thereof so that when the electrodes are in said second position the arc travels towards the open end of said cavity; and a permanent magnet sleeve embracing the first electrode and magnetized in the longitudinal direction of the annular space to create a magnetic field in said annular space in the longitudinal direction thereof, the length of said annular space being greater than at least a major portion of the distance the arc travels in a half cycle, whereby as the electrodes are moved from the first position to the second position the arc is struck at the base of the cavity and spirals towards the open end thereof until substantially current zero.

4. An alternating current vacuum switch mechanism of the type in which a circuit-interrupting arc is maintained by vaporized electrode materials substantially to current zero before interruption, the mechanism comprising in combination: means defining a vacuum space; a first electrode having at least portions within said space and of elongated cup shaped conformation with a cylindrical outer wall and an elongated cylindrical cavity having a base; a second electrode telescopically received in said cavity and of conical conformation to define an elongated annular space with respect to said cavity and having gradually increasing cross-sectional area as the base of the cavity is approached; said electrodes being movable relative to each other in the longitudinal direction of said annular space, said movement being between a first position in which the electrodes are in contact-making relationship at the base of said cavity and a second position in which said electrodes are out of contact; and a permanent magnet sleeve embracing the first electrode and magnetized in the longitudinal direction thereof to create a magnetic field in said annular space in the longitudinal direction thereof, the length of said annular space being greater than at least a major portion of the distance the arc travels in a half cycle whereby as the electrodes are moved from the first position to the second position the arc is struck at the base of the cavity and spirals towards the open end thereof until substantially current zero.

5. An alternating current vacuum switch mechanism of the type in which a circuit-interrupting arc is maintained by vaporized electrode materials substantially to current zero before interruption, the mechanism comprising in combination: means defining a vacuum space; a first electrode having at least portions within said space and of elongated cup shaped conformation defining a cavity said space having a base and open end within said space; a second electrode telescopically received in said cavity and of tapering conformation to define an elongated annular space with respect to said cavity and having gradually increased cross-sectional area as the base of the cavity is approached said electrodes being movable relative to each other in the longitudinal direction of said annular space, said movement being between a first position in which the electrodes are in contact-making relationship at the base of said cavity and a second position in which said electrodes are out of contact; and means creating a magnetic field longitudinal of said annular space, the length of said annular space being greater than at least a major portion of the distance the arc travels in a half cycle whereby as the electrodes are moved from the first position to the second position the arc is struck at the base of the cavity and spirals towards the opening thereof until substantially current zero.

6. An alternating current vacuum switch mechanism

of the type in which a circuit interrupting arc is maintained by vaporized electrode materials substantially to current zero before interruption, the mechanism comprising in combination: means defining a vacuum space; a first electrode having at least portions within said space and defining an elongated cavity with an open end and base; a second electrode telescopically received in said cavity and defining a longitudinal annular space in relation to the first electrode; said electrodes being movable relative to each other in the longitudinal direction of the annular space, said movement being between a first position in which the electrodes are in contact-making relationship at the base of said cavity and a second position in which said electrodes are out of contact; means including a conductor in circuit with said electrodes when in said second condition defining a circumferential magnetic field along at least an element of said annular space, whereby an arc is moved towards said open end when under the influence of said field; and means to create a magnetic field longitudinal of said annular space to rotate the arc circumferentially about the annular space and repeatedly through the zone of influence of the circumferential magnetic field, the length of said annular space being greater than at least a major portion of the distance the arc travels in a half cycle, whereby as the electrodes are moved from the first position to the second position the arc is struck at the base of the cavity and travels on a spiral-like path towards the open end thereof until current zero.

7. An alternating current vacuum switch mechanism of the type in which a circuit-interrupting arc is maintained by vaporized electrode material substantially to current zero for interruption, the mechanism comprising in combination: means defining a vacuum space; a first electrode extending through said means to define a first circuit terminal outside said space, said electrode defining a cavity having a space and an open end within said space, the base of said cavity having a centrally located secondary board defining an annular lip at its junction with the base; a second electrode telescopically received in said cavity and extending outside said space to define a second circuit terminal outside said space, said second electrode forming an elongated annular portion in relation to said first electrode; said electrodes being movable relative to each other in a longitudinal direction along the annular space, said movement being between a first position and in which the electrodes are in contact-making relationship at said lip and a second position in which said electrodes are out of contact; means for causing an arc which exists between said electrodes in said second position to be impelled from the base end of said cavity to the open end thereof; and means creating a magnetic field longitudinal of said annular space, said magnetic field being effective to cause said arc to rotate circumferentially around said annular space under the influence thereof, the sum total of the motions of said arc describing a helical path within said annular space, the length of said annular space being greater than at least a major portion of the longitudinal distance said arc travels in a half cycle, so that said arc is extinguished before reaching the open end of said cavity.

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