Dec. 19, 1961 J. D. COBINE ET AL 3,014,107

VACUUM SWITCH

Filed Jan. 2, 1959

Fig. 1.

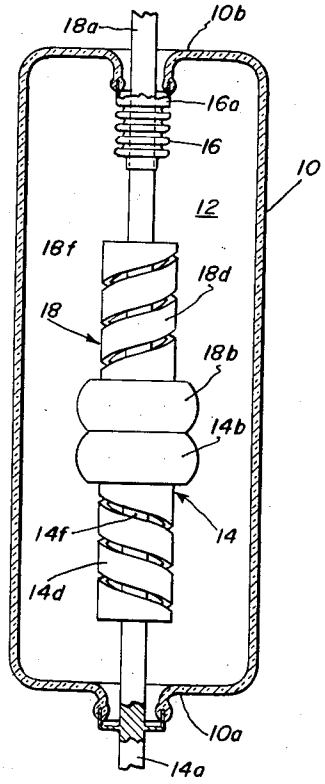


Fig 3

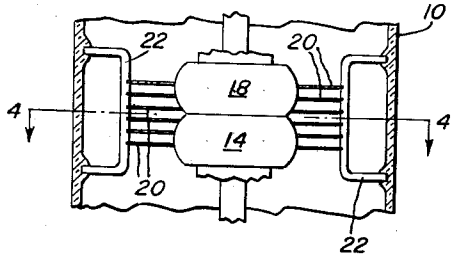


Fig. 4.

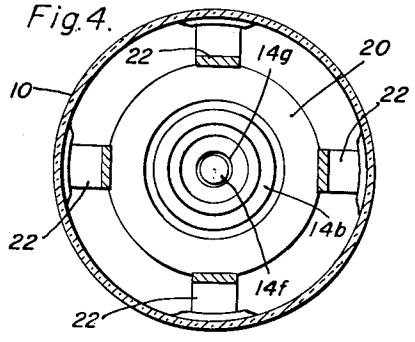
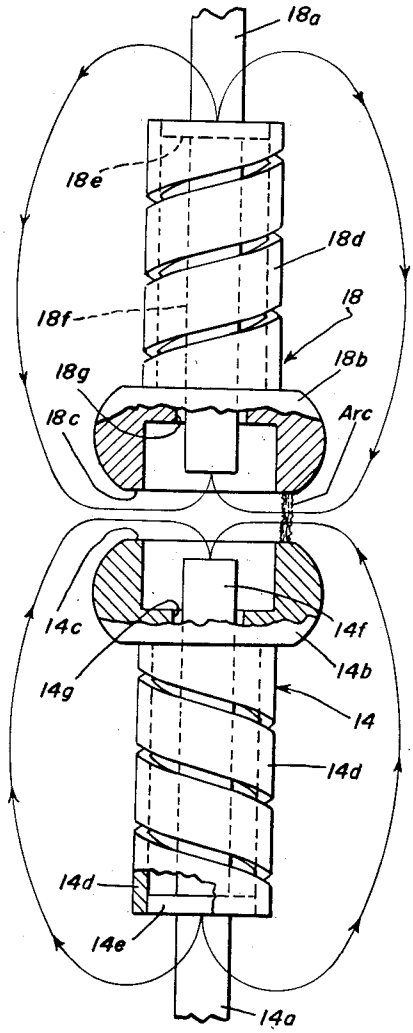


Fig. 2.



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United States Patent Office 3,014,107 Patented Dec. 19, 1961

3,014,107

VACUUM SWITCH

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Filed Jan. 2, 1959, Ser. No. 784,726
4 Claims. (Cl. 200—144)

The present invention relates to an improved vacuum type switch for alternating current circuits in which an arc is formed on circuit opening and sustained until substantially current zero is reached. The present invention is particularly directed to a switch of this type using an electrode material having a relatively high vapor pressure in conjunction with a unique mechanical construction that maintains rapid arc motion over the electrodes until the current zero is substantially reached.

In vacuum type switches current flow between the electrodes is maintained by the ionized vapor formed by the electrode material itself. Such vapor is formed by the heat and other effects of the arc at the points of contact between the arc and the electrode faces. If the switch is to carry an alternating current until substantially the zero current condition, it is necessary to utilize an electrode material that vaporizes without undue difficulty. Such electrode materials, however, are readily eroded by the arc and thus tend to deteriorate rapidly in actual commercial switching applications.

The vacuum switch of the present invention is defined by an insulating envelope within which a pair of relatively movable electrodes are located. At least the arcing surfaces of these electrodes are of readily vaporized material. Removed from the arcing surfaces, the electrodes define oppositely wound facing solenoids, within which are preferably placed magnetic cores serving to concentrate and maximize the radial fringing flux in the space between the arcing surfaces. This radial fringing flux imparts a rotational movement to the arc, causing it to travel over a large electrode area and preventing undue localized electrode erosion. Further in accordance with the present invention, the contours of the arcing surfaces of the electrodes are made to substantially follow the direction of the magnetic field, thereby orienting the arc in transverse relation to the magnetic field and assuring maximum motion of the footpoints of the arc and minimizing the tendency of the arc to dwell in any single region of an electrode.

It is therefore a general object of the present invention to provide an improved vacuum switch for alternating current circuits in which a readily vaporized electrode material is used in conjunction with magnetic action to provide ample ionized metal vapor to sustain the arc until substantially current zero, while at the same time distributing the electrode erosion over a large area of each electrode.

A more particular object of the present invention is to provide apparatus of the foregoing type in which the electrodes themselves provide the necessary magnetic field.

Still another object of the present invention is to provide an improved vacuum switch combining a pair of contact members, each including means for establishing and maintaining a circuit interrupting arc and self induced magnetic means for keeping the arc in motion until extinction.

Our invention further resides in a switch of the foregoing type having features of construction, combination and arrangement making it simple in construction, reliable in operation, readily manufactured and operated and in other respects serving to provide a device having maximum commercial usefulness.

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 connection with the accompanying drawings in which:

FIG. 1 is an axial cross-sectional view with parts in elevation of a complete switch constructed in accordance with the present invention;

FIG. 2 is a greatly enlarged fragmentary view in elevation of the electrodes of the switch of FIG. 1, showing the same in the contacting circuit-opening position;

FIG. 3 is a fragmentary view of a modified form of the switch of FIGS. 1 and 2; and

FIG. 4 is a cross-sectional view along axis 4—4, FIG. 3.

As shown in FIG. 1, a switch constructed in accord with our inventin may comprise an envelop **10** of glass or other suitable vacuum-tight insulating material. This envelop defines the vacuum space **12**. At end **10***a*, the envelop **10** embeds the stem **14***a* of the fixed electrode **14**, described in further detail hereafter. At its opposite end **10***b* the envelop embeds the flange **16***a* of the vacuum tight bellows **16**. These bellows receive and movably support the stem **18***a* of the movable electrodes **18**, described in further detail hereafter. The stem **18***a* is attached to suitable operating mechanism (not shown) to move the electrode **18** in the axial direction between the spaced closed circuit position in relation to electrode **14** as shown in FIG. 1 and the open-circuit position shown in FIG. 2. Envelop **10** is evacuated and maintained at a pressure of at least as low as 10^{-4} mm. of mercury in order that no ionizable gases be present to impede vacuum circuit interruption.

The detailed construction of the electrodes **14** and **18** is seen best in FIG. 2. As shown, the electrode **14** has a head end **14***b* in the form of a solid of revolution about the axis of the electrodes and defining the annular flat contacting face **14***c*. Opposite the face **14***c*, the head **14***b* receives the helical solenoid-defining conductor **14***d* which spirals as shown to be received on the flanged disk-shaped end **14***e* of the stem **14***a* as shown in the broken away portion of FIG. 2. These parts may be secured together by welding, brazing or other suitable means.

The cylindrical magnetic core **14***f* is disposed within the solenoid **14***d*, as shown. It is affixed at one end to the flanged end **14***e* of the stem **14** *a* preferably by suitable means to provide mechanical support and electrical insulation. This core is of any suitable material having a high magnetic permeability, such as soft iron, silicon steel, etc. As shown in FIG. 2, the core extends the full length of the solenoid **14***d* and through the circular bore **14***g* in the head **14***b* to a point close to the plane defined by the contact-making annular face **14***c*. As shown, the core **14***f* is within the confines of the solenoid **14***d* and the head **14***b*.

The electrode **18** is constructed in fashion similar to electrode **14**. Its head portion **18***b* is likewise a solid of revolution about the axis of the electrodes defining a flat annular face **18***c* of the electrode **18**. A conductor **18***d* in the form of a solenoid is affixed to the face of head **18***b* opposite the annular face **18***c* and spirals as shown in FIG. 2. It will be noted that this conductor spirals in opposite sense to the spiral of the conductor **14***d*. At its end opposite head **18***b*, the solenoid conductor **18***d* is received over the flanged end **18***e* of the stem **18***a*. The magnet core **18***f*, FIG. 2, is disposed within the solenoid conductor **18***d* and is insulatingly affixed to the flanged end **18***e* of the stem **18***a*. This core extends through the bore **18***g* of the head **18***b* in fashion similar to the core **14***f* to terminate near the plane of face **18***c*, and within the confines of head **18***b*.

The parts of electrode **18** are secured to each other by suitable means. The core **18***f* is of suitable high permeability material to that of the core **14***f*.

The head portions **14***b* and **18***b* of the electrodes, or at least facing surfaces thereof, are made of materials chosen in accordance with the invention set forth in Lee and Cobine patent application S.N. 750,784, filed July 24, 1958, and assigned to the same assignee as the present invention. Such materials are characterized by the ability to vaporize relatively easily under the action of the arc and by other characteristics more particularly set forth in that application. Examples of such materials include tin, antimony, lead, zinc, manganese, bismuth, and suitable alloys thereof. These electrodes may also be made of a moderate vapor pressure material, such as copper or silver, as well. The other current-conducting portions of the electrodes are made of any suitable conducting materials having the required mechanical strength and current-carrying capacity. The vapor supplying materials are suitably refined in vacuo as set forth in the Lee and Cobine application to preclude the release of ionizable gases during operation.

As above noted, the solenoids defined by the conductors **14***d* and **18***d* are wound or spiral in opposite senses. Consequently, when a current flows between the electrodes (either by reason of their contacting relation as in FIG. 1 or by reason of an arc between heads **14***b* and **18***b*), opposing magnetomotive forces are developed. These forces are directed along the axis of the electrodes since the solenoids spiral about this axis. The resultant magnetic field distribution is determined by the action of the cores **14***f* and **18***f*, which define relatively low permeability magnetic paths. These paths terminate at the inboard end faces of the cores **18***f* and **14***f* where the magnetic fields fringe radially out to turn back about the respective solenoids to the outboard ends of the cores. A representative magnetic flux line about the solenoid **18***d* is shown at F, FIG. 2. It will be noted that this flux line fringes out in direction substantially parallel to the faces **14***c* and **18***c* and then swings back in direction generally parallel to the side face configuration of the head portion **18***b* of the electrode **18**. There are of course many flux lines making up the overall field defined by the solenoid conductors **14***d* and **18***d* and the cores **14***f* and **18***f*. All of these tend to spread radially out near the neutral plane midway between the electrodes and curve back away from the electrodes in manner similar to the flux line F, FIG. 2.

The effect of the magnetic flux resulting from the action of the solenoid portions of the electrodes is to rotate the arc about the axis of the electrodes. Under normal current conducting conditions, the electrodes are positioned with their faces **14***c* and **18***c* in contact-making relation as shown in FIG. 2. When the electrodes are separated as in FIG. 2, an arc is struck between faces **14***c* and **18***c* at the moment of interruption (assuming, of course, that electrode opening does not occur at a current zero). Since this arc is generally in the direction of the axis of the electrodes, and since the magnetic field in this region is generally radial, the effect of the action of the arc current and the magnetic field is to cause the arc to rotate about the axis of the electrodes, traversing the facing electrode surfaces at a rapid rate. Normally the arc will tend the climb up on the arcuate faces of the electrodes in response to inherent magnetic blow-out action, but due to the magnetic field distribution associated with the action of the cores and the solenoid portions of the electrodes the rotation about the axis of the electrodes continues. Thus, the arc continuously rotates about the surfaces of the electrodes, is continually travelling onto fresh electrode area, and the action of the arc is distributed over a large area of the electrodes.

The contour of the arcing surfaces of head portions **18***b* and **14***b* of the respective electrodes is chosen in accordance with the shape of the magnetic fields due to

the solenoid portions of these electrodes and the cores **14***f* and **18***f*. As shown by the flux line F, FIG. 2, the contour is such that the arcing surfaces are generally parallel to the flux lines. The arc is accordingly substantially normal to the magnetic flux lines at its "footpoints" of contact with the electrodes so that there is a large component of the current flow at right angles to the magnetic flux. This assures that a maximum interaction takes place between the magnetic field and the arc current and that there is no tendency of the arc to approach a point of limited magnetic action and dwell without substantial further movement.

In the embodiment of the invention shown in FIG. 3, a plurality of annular deionizing plates **20** are located in alignment with and external of electrodes **14** and **18**. These plates may be of any suitable deionizing material, such as for example, a metal such as copper. These plates also define cool surfaces upon which the evaporated electrode material can condense without impairing the insulating ability of the inside faces of the envelop **10**. The plates **20** are held in position by suitable support brackets **22** affixed to the walls of envelop **10**.

In the switch of the present invention, at least the arcing faces of the electrodes **14** and **18** are made of materials that produce relatively copious amounts of vaporized metal. Nevertheless no undue electrode erosion occurs because the arc travels over a large area on each electrode and, in addition, the arc does not at any time tend to dwell at any one position.

It will be noted that the head or arcing portions of, the electrodes, **14***b* and **18***b*, define axial cylindrical bores in which the cores **14***f* and **18***f*, respectively, are located. Since these cores extend almost to the planes of the annular contact-making surfaces **14***c* and **18***c*, they are particularly effective in creating magnetic field patterns that are essentially radial in the regions of the faces **14***c* and **18***c*. However, the cores are within the confines of the head portions **14***b* and **18***b*. For this reason, coupled with the evacuated character of the space in which the electrodes are located, the arc does not tend to form at or travel to these cores.

While we have shown and described specific forms of the present invention it will of course be understood that many modifications and alternative constructions can be made without departing from its spirit and scope. 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 in which a circuit interrupting arc is maintained by vaporized electrode material until substantially current zero, the switch comprising: means defining a vacuum space having a pressure at least as low as 10^{-4} mm. of mercury; a pair of electrodes symmetrical about a common axis and located in said space in opposed relation to define facing arcing surfaces, said electrodes being movable along said axis between a contact-making engaging position and a spaced position establishing a circuit interrupting arc therebetween, each electrode having a head portion and a stem portion, said head portion having an axial bore therein and defining an annular contact face, a solenoid member operatively connecting said head and stem portions, a high permeability magnetic core located within the confines of said solenoid member insulatingly connected to said stem portion and extending through the axial bore of said head portion to a position near the plane of said annular contact face, each of said solenoids spiraling in opposite sense to produce substantially identical opposed magnetic fields, said magnetic fields determined by said cores and being substantially parallel with the axis of said electrodes and fringing radially adjacent said annular contact faces, the arcing surfaces of said electrodes having substantially the same shape as the flux lines of said magnetic field, said

magnetic field so influencing the circuit interrupting arc established through the vaporized metal of the electrodes that said arc forms with footpoints substantially normal to said magnetic field rotates about the axis of said electrodes and is maintained on said arcing surfaces until substantially current zero is reached.

2. The vacuum switch of claim 1 wherein the head portion of said electrode has a generally toroidal configuration.

3. An alternating current vacuum switch in which a circuit interrupting arc is maintained by vaporized electrode material until substantially current zero, the switch comprising: means defining a vacuum space having a pressure at least as low as 10^{-4} mm. of mercury; a pair of electrodes symmetrical about a common axis and located in said space in opposed relation to define facing arcing surfaces, said electrodes being movable along said axis between a contact-making engaging position and a spaced position establishing a circuit interrupting arc therebetween, each electrode having a head portion and a stem portion, said head portion having an axial bore therein and defining an annular contact face, a solenoid member operatively connecting said head and stem portions, a high permeability magnetic core located within the confines of said solenoid member insulatingly connected to said stem portion and extending through the axial bore of said head portion to a position near the plane of said annular contact face, each of said solenoids spiraling in opposite sense to produce substantially identical opposed magnetic fields, said magnetic fields determined by said cores and being substantially parallel with the axis of said electrodes and fringing radially adjacent said annular contact faces, the arcing surfaces of said electrodes having substantially the same shape as the flux lines of said magnetic field, said magnetic field so influencing the circuit interrupting arc established through the vaporized metal of the electrodes that said arc forms with footpoints substantially normal to said magnetic field rotates about the axis of said electrodes and is maintained on said arcing surfaces until substantially current zero is reached, and a plurality of annular plates located within said vacuum space in surrounding spaced relationship to the head portions of said electrodes, said annular plates providing condensing surfaces for said vaporized metal.

4. An alternating current vacuum switch in which a circuit interrupting arc is maintained by vaporized electrode material until substantially current zero, the switch comprising: means defining a vacuum space having a pressure at least as low as 10^{-4} mm. of mercury; a pair of electrodes symmetrical about a common axis and located in said space in opposed relation to define facing arcing surfaces, the arcing surfaces of at least one of said electrodes being formed of a material selected from the group consisting of tin, antimony, lead, zinc, manganese, bismuth and alloys thereof, said electrodes being movable along said axis between a contact-making engaging position and a spaced position establishing a circuit interrupting arc therebetween, each electrode having a head portion and a stem portion, said head portion having an axial bore therein and defining an annular contact face, a solenoid member operatively connecting said head and stem portions, a high permeability magnetic core located within the confines of said solenoid member insulatingly connected to said stem portion and extending through the axial bore of said head portion to a position near the plane of said annular contact face, each of said solenoids spiraling in opposite sense to produce substantially identical opposed magnetic fields, said magnetic field determined by said cores and being substantially parallel with the axis of said electrodes and fringing radially adjacent said annular contact faces, the arcing surfaces of said electrodes having substantially the same shape as the flux lines of said magnetic field, said magnetic field so influencing the circuit interrupting arc established through the vaporized metal of the electrodes that said arc forms with footpoints substantially normal to said magnetic field rotates about the axis of said electrodes and is maintained on said arcing surfaces until substantially current zero is reached.

References Cited in the file of this patent

UNITED STATES PATENTS

Re. 21,087	Rankin	May 16, 1939
1,925,858	Baker	Sept. 5, 1933
2,411,892	Peters	Dec. 3, 1946
2,411,893	Peters	Dec. 3, 1946
2,900,476	Reece	Aug. 18, 1959

FOREIGN PATENTS

703,101	Great Britain	Jan. 27, 1954
787,846	Great Britain	Dec. 18, 1957