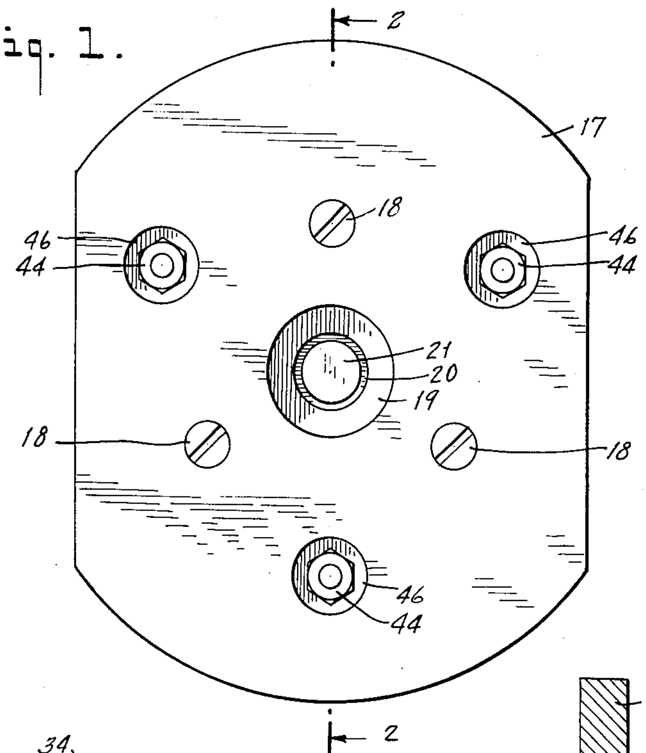
April 23, 1963 J. R. BEERS ET AL 3,087,034

VACUUM SWITCH

Filed June 20, 1960 2 Sheets-Sheet 1

Fig. 1.



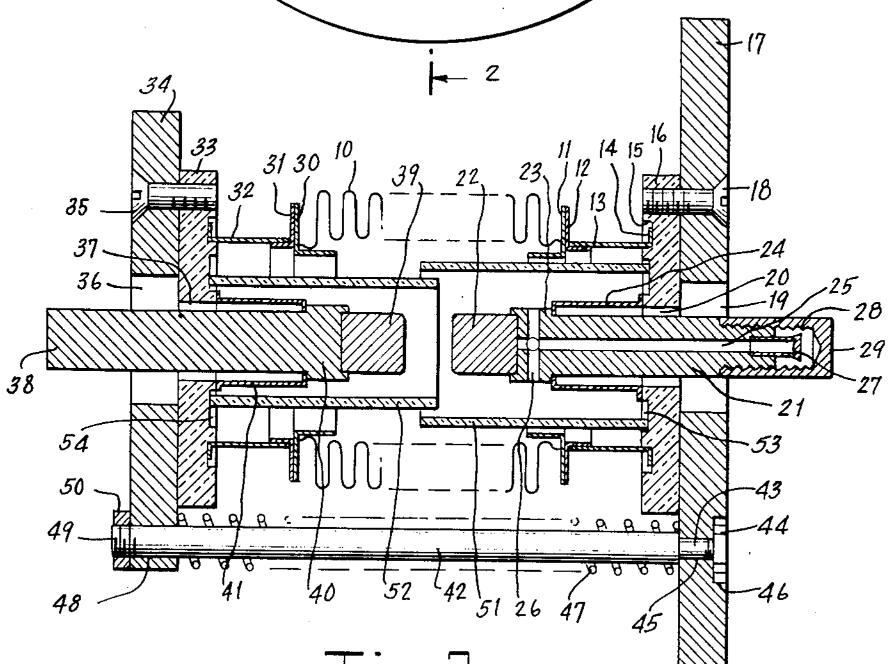


Fig. 2.

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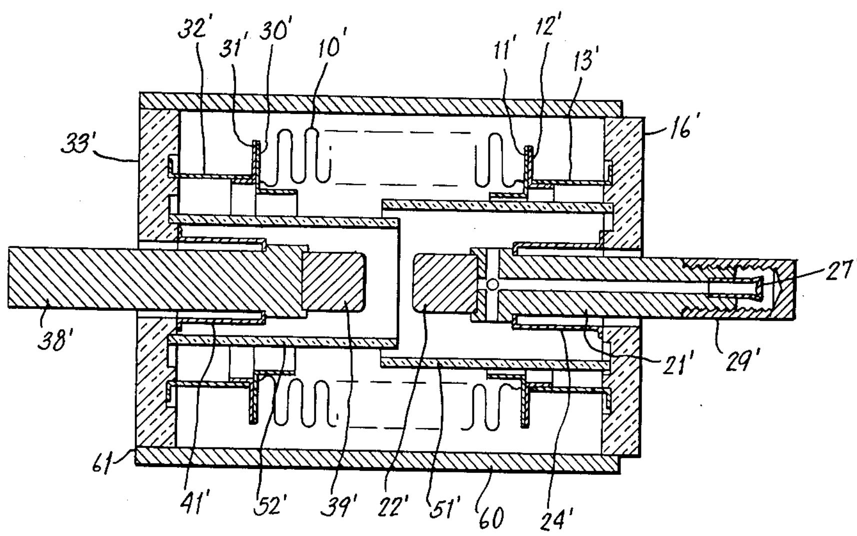
Fig. 3.



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VACUUM SWITCH

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This invention relates to switches, and more particularly to an improved vacuum switch especially adapted for high voltage, high current applications.

Vacuum switches are switches in which the switch contacts are disposed in a vacuum to minimize arcing and voltage breakdown conditions. In the usual form of construction, the switch contacts are disposed within an evacuated envelope formed by a tubular housing having one end thereof sealed by an inwardly-extending, metallic, tubular bellows which carries the movable switch contact, and the other end thereof sealed by means which acts to support the fixed switch contact. A bearing structure is provided within the bellows to permit axial movement of the movable switch contact with respect to the fixed switch contact by elongating or compressing the bellows. By virtue of this arrangement, the switch may be opened and closed without destroying the vacuum.

When vacuum switches of this type are utilized for high voltage, high current applications, they are subject to mechanical failure, such as "binding," and have a relatively short operating life. This follows because the bellows and the bearing structure must, of necessity, form a portion of the current-carrying path through the switch, with the result that they become excessively heated when carrying high current. Furthermore, during operation of the switch, the metallic bellows is stretched or elongated from its neutral or "at rest" position to effect closure of the switch contacts. Since metallic bellows generally provide more satisfactory service and have a longer operating life when they are subject to compression rather than expansion from their neutral position, vacuum switches of this type possess a relatively short operating life because of the likelihood of metal fatigue and consequent failure in the bellows structure. Finally, once the vacuum switch has been assembled and evacuated to provide the desired vacuum therein, there is no way to coat the tubular bellows with a suitable lacquer or other substance to seal the metal "pores" of the bellows to prevent shelf deterioration of the vacuum.

Accordingly, it is a primary object of this invention to provide a vacuum switch which is especially adapted for high voltage, high current applications.

It is a further object of this invention to provide a vacuum switch which does not possess the above-mentioned disadvantages of the heretofore known switches of this type, and which is adapted for manufacture without the "high skill" techniques required for production of the heretofore known types.

It is a still further object of this invention to provide a vacuum switch which may be readily converted from "normally-opened" to "normally-closed" switch operation, or vice versa, by means of only a simple change in manufacturing technique.

Briefly, the vacuum switch of the invention comprises an evacuated envelope formed by a tubular bellows structure having both ends thereof sealed by closure means which support the switch contacts, so that both switch contacts are disposed within the bellows and the bellows itself acts as the switch housing. A bearing structure is provided exteriorly of the bellows to support and guide the closure means to permit relative axial movement between the switch contacts for operating the switch. In one form of the invention, the bearing structure comprises a plurality of rods or shafts which are anchored at one end to one

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of the closure means and have the other closure means slidably mounted on the other end thereof, so that the closure means are adapted for relative axial movement with respect to each other. In another form of the invention, the bearing structure comprises a piston-like arrangement, wherein one of the closure means acts as a piston and is slidably mounted within a cylindrical support structure which is anchored to the other closure means, so that the first closure means axially slides within the cylindrical support to open and close the switch contacts.

By virtue of the foregoing construction of the vacuum switch of the invention, the bellows and bearing structures for the switch do not themselves carry the switch current, so that heating of these critical operating parts of the switch is minimized. This, of course, reduces the possibility of operating failures, such as binding, for example, and permits the vacuum switch of the invention to handle large amounts of power. Furthermore, since the outer surface of the bellows structure is readily accessible even after the device has been evacuated, a coating of lacquer or other suitable sealing compound may be applied to the bellows to seal the pores thereof to prevent deterioration of the vacuum and thereby assure a long "shelf-life" for the switch. Additionally, since the bearing structure for the switch is located exteriorly of the bellows structure, spring biasing means may be employed to counteract a portion of the external atmospheric pressure on the switch, to thereby permit the switch to be operated with much smaller forces than possible with known vacuum switch arrangements. The spring biasing means also serves to minimize "chattering" or bouncing of the switch contacts during operation and thereby prevents rapid deterioration of the contacts caused by the formation of multiple arcs. By assembling the vacuum switch of the invention with the tubular bellows structure in its neutral or "at rest" position prior to evacuation so that evacuation compresses the bellows, the switch may be operated with the bellows under compression rather than expansion, to thereby lengthen the service life of the bellows structure. Finally, the unique construction of the vacuum switch of the invention is readily adapted to mass production techniques by means of jigs and fixtures and the like, to thereby eliminate the "high skill" operations, such as glass to metal sealing, for example, presently required in the manufacture of the heretofore known constructions.

In the drawings:

FIG. 1 is an end elevational view of a vacuum switch constructed in accordance with the teachings of the invention;

FIG. 2 is a side sectional view of the switch of FIG. 1 taken along the line **2—2** of FIG. 1; and

FIG. 3 is a side sectional view of a vacuum switch similar to the switch of FIGS. 1 and 2, but employing a different form of bearing structure.

Referring now to FIGS. 1 and 2 of the drawings, there is shown a vacuum switch comprising a tubular bellows structure **10** which may be formed of any suitable material, such as copper, for example. One end of the bellows is sealed with a vacuum-tight seal to a cylindrical, wide bellows flange **11**. The vacuum-tight seal may be made by any suitable means, such as brazing, for example. The wide bellows flange **11** is similarly sealed to a narrow bellows flange **12**, which is also of cylindrical shape. A cylindrical flange **13** having a flared "lip," or end portion **14** is sealed with a vacuum-tight seal to a lip formed on the narrow bellows flange **12**. The lip **14** of the flange **13** is sealed with a vacuum-tight seal in an annular groove **15** formed in a circular header **16**. The header **16** is preferably formed of an electrical insulating material, such as ceramic, for example. The flanges **11**, **12** and **13** may be formed of a suitable material, such as Kovar, for example, which has a temperature coefficient of expansion suitable for making vacuum-tight connections with the ceramic header 16 and the copper bellows 10. The ceramic header 16 is secured to a mounting plate 17 by means of screws 18, so that the mounting plate may be employed to mount and support the entire switch assembly if desired. Mounting plate 17, in the same manner as header 16 is preferably formed of an electrical insulating material, such as ceramic, for example. The mounting plate has a circular opening 19 which is concentrically arranged with a somewhat smaller circular opening 20 formed in the header 16. Both openings serve to receive a conductor 21 having a contact 22 secured to the inner end thereof. The conductor 21 may be in the form of a rod, as illustrated, and should be formed of a material having good electrical conducting characteristics, such as copper, for example. The contact 22 is formed of a material, such as tungsten or a tungsten alloy, having the ability to withstand the arcs formed during the make and break operations of the switch without appreciable pitting or other deterioration. Conductor 21 has a raised shoulder 23 adjacent the inner end thereof to receive a cylindrical flange 24, which is sealed with a vacuum-tight seal to the shoulder and to the inner surface of the ceramic header 16. The flange 24 is preferably formed of a material, such as Kovar, for example, having a temperature coefficient of expansion which permits a good vacuum-tight seal to be made to both the ceramic header and the copper conductor.

As thus far described, it is believed apparent that one end of the tubular bellows structure 10 is closed with a vacuum-tight seal by means of flanges 11, 12 and 13, header 16, flange 24, and conductor 21. To permit evacuation of the bellows, the conductor 21 is axially bored at 25 and radially bored at 26, so that the interior of the bellows is connected to the external atmosphere by means of the communicating passages 25 and 26. An exhaust tip 27 of copper, or other suitable material, is brazed to the outer end of passageway 25, so that the device may be sealed after evacuation, by "pinching off" the tip 27. The outer end of conductor 21 is externally threaded at 28 to receive a protective end cap 29, which again is preferably formed of a material having good electrical conducting characteristics. By virtue of this arrangement, the switch contacts 22 is supported by the conductor 21 and is electrically connected by the conductor 21 to the outside of the switch without destroying the vacuum-tight seal. Therefore, if desired, the end cap 29 may comprise one terminal for connecting the switch to an external circuit. The other end of the bellows 10 is similarly mounted, by means of a wide bellows flange 30, a narro wbellows flange 31, and a cylindrical flange 32, on another header 33 of ceramic material or the like. Header 33 is secured to an end plate 34 by means of a plurality of screws 35. Again, the end plate 34 is preferably formed of electrical insulating material, such as ceramic, for example. End plate 34 and header 33 are respectively formed with circular openings 36 and 37 to receive a second conductor 38 having a contact 39 secured to the inner end thereof. The inner end of conductor 38 is formed with a shoulder portion 40 to engage a flange 41 which serves to mount the conductor on the ceramic header 33 with a vacuum-tight seal. Flange 30, 31 and 32, header 33, conductor 38 and flange 41 cooperate in the same manner as the corresponding elements on the other end of the bellows to close the bellows with a vacuum-tight seal, with conductor 38 forming the other terminal of the switch.

A plurality of guide rods 42 are concentrically disposed around the bellows structure 10 to permit axial movement between the end of the bellows. Each of the rods 42 is formed with a reduced diameter portion 43 which is threaded to receive a nut 44. The reduced diameter portion 43 is seated in an opening 45, the opening being counter-bored at 46 to permit flush mount-

ing of the nuts 44. By virtue of this arrangement, one end of each of the guide rods 42 is securely anchored to the mounting plate 17. A helical spring 47 is arranged around each of the guide rods 42 between the end plates 17 and 34. End plate 34 is formed with an opening 48 to receive the other end 49 of each of the guide rods in a sliding fit, to thereby permit relative axial movement between the two end plates against the force of the spring 47. The ends 49 of the guide rods 42 are externally threaded to engage stop nuts 50 which act to limit the outward axial movement of the end plates. Finally, a pair of concentrically mounted, vapor shields 51 and 52 are respectively brazed to annular grooves 53 and 54 formed in the headers 16 and 33 to prevent migration of the tungsten vapors formed during operation of the switch contacts to areas of the switch where the deposition of the vaporized tungsten might result in a short circuit. In practice, the vapor shields 51 and 52 may be formed of ceramic, glass, metal, or other convenient material.

When the vacuum switch has been assembled just prior to evacuation, the contacts 22 and 39 are arranged to be spaced a predetermined distance apart with the bellows 10 in its neutral or "at rest" position. The switch is then evacuated by any of the well known methods through the inter-connecting passages 25 and 26 in conductor 21, and the exhaust tip 27 is pinched-off to seal the evacuated device. Since the external or atmospheric pressure now exceeds the pressure within the bellows, header 33 and end plate 34 will axially move along the guide rods 42 towards header 16 and mounting plate 17, so that switch contact 39 is moved into engagement with switch contact 22. The vacuum switch therefore becomes a "normally-closed" switch, which may be opened by axially moving the end plates away from each other against the force of the external atmospheric pressure which tends to maintain the switch contacts in closed position. While specific means for opening the switch contacts have not been illustrated, it will be understood that any of the known devices, such as solenoids, for example, for performing this operation may be utilized. While the helical springs 47 are shown in the drawing as surrounding the guide rods 42, it will be understood that they may be omitted, if desired, when the switch is utilized as a normally-closed switch, since the pressure differential tends to maintain the contacts in closed position. The springs 47 may be utilized to counterbalance a portion of the atmospheric pressure which tends to urge the contacts 22 and 39 together so that only a very small force is required to separate the contacts. Accordingly, a very small solenoid, or other device, may be employed to actuate the vacuum switch of the invention. When it is desired to operate the switch as a "normally-open" switch, the force of the springs 47 may be made larger than the pressure differential which tends to urge the switch contacts together, so that the switch contacts are maintained in a normally separated condition and may be closed upon the application of an externally applied axial force. It is therefore believed evident that the novel structure of the vacuum switch of the invention permits conversion from "normally-open" to "normally-closed" operation, or vice versa, by merely changing the strength of the springs 47.

It may be noted that the current-carrying path through the switch does not include the tubular bellows structure 10 and the external bearing structure comprising the guide rods 42, so that the switch may be utilized for high voltage, high current applications without undesirable heating of the bellows and bearing structures which might cause mechanical failure of the switch. Furthermore, since the vacuum switch is assembled with the bellows in its neutral position, and the bellows is then compressed during evacuation of the device, the bellows is operated in compression rather than expansion, so that the useful service life of the bellows is materially increased. Additionally, if desired, a suitable lacquer or other sealer may be applied to the outer surface of the bellows **10** to seal the pores of the metal, to thereby prevent deterioration of the vacuum and assure a long shelf-life for the device. Finally, by utilizing the biasing springs **47**, the operating force required to actuate the switch may be suitably adjusted to minimize or prevent "chattering" or bouncing of the switch contacts during operation of the switch, to thereby prevent the formation of multiple arcs which may cause deterioration of the contacts.

Although the embodiment of FIGS. 1 and 2 of the drawings illustrates the vacuum switch of the invention with end plates **17** and **34** for mounting the switch, it will be understood that the end plates may be omitted, if desired, and the guide rods **42** connected between the ceramic headers **16** and **33**. Furthermore, the switch may be operated by applying the axial operating force directly to the conductors **21** and **38**, so that the vacuum switch of the invention is adapted for extremely compact packaging and may be fabricated with a bare minimum of parts. Additionally, the concentric mounting arrangement for the ends of the bellows **10** in the ceramic headers **16** and **33** permits the switch to be easily manufactured by means of jigs, fixtures, and the like, which eliminate the necessity for the use of high-skill techniques, such as glass-to-metal sealing, heretofore employed.

FIG. 3 of the drawings illustrates an alternative embodiment of the invention in which the external bearing structure for the vacuum switch comprises a cylinder and piston arrangement. In describing the device of FIG. 3, the same reference numerals, but with a prime notation, will be employed to designate elements which are the same as the elements of the switch of FIGS. 1 and 2. As seen in FIG. 3, a cylindrical support **60** of ceramic or other insulating material is secured at one end **61** thereof by any suitable means, such as cementing, for example, to the outer peripheral portion of the ceramic header **33'**. The other ceramic header **16'** is arranged to fit within the other end of the cylinder **60** with a sliding fit so that it operates as a piston when the switch is actuated to open and close the contacts **22'** and **39'**. In all other respects, the embodiment of FIG. 3 of the drawings is identical in construction and operation of the embodiment of FIGS. 1 and 2 of the drawings. The vacuum switch shown in FIG. 3 may be operated by applying the axial operating force directly to the conductors **21'** and **38'**, so that the switch is adapted for manufacture with a bare minimum of parts.

It is believed apparent that many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof. For example, a tubular bellows structure having a cross-sectional shape other than circular could be employed, and the shapes of the headers and conductors altered to accommodate a particular application. Bearing structures other than the guide rods and the cylinder and piston arrangement illustrated could be utilized, if desired. Additionally, by suitably insulating and arranging the conductors, plural switch contacts could be employed. Accordingly, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A vacuum switch adapted for high voltage, high current applications, comprising an evacuated envelope formed by a tubular bellows structure and first and second closure members, said first and second closure members being formed of an electrical insulating material and being respectively permanently secured to the opposite ends of said bellows structure with vacuum-tight seals, to thereby form a vacuum-tight enclosure within said bellows structure; first and second contact means disposed within said bellows structure; means for respectively mounting said first and second contact means on said first and second closure members within said bellows structure, so that each of said contact means is adapted for movement with the closure member associated therewith and is adapted to engage the other contact means upon relative axial movement between said closure members; and an axially extending bearing structure surrounding said bellows structure between said closure members for interconnecting said closure members to permit relative axial movement therebetween, whereby said contact means are adapted to be opened and closed by relative axial movement between said closure members.

2. A vacuum switch as claimed in claim 1, wherein said means for mounting said contact means comprises a rod of electrically conductive material having the contact means associated therewith mounted on one end thereof and having the other end thereof passing through the closure member associated therewith, said rod being permanently secured to said closure member with a vacuum-tight seal to form a terminal for connecting the switch to an external circuit.

3. A vacuum switch as claimed in claim 2, further comprising a pair of axially disposed, concentrically arranged, cylindrical vapor shields surrounding said contact means and respectively mounted on said first and second closure members for movement therewith.

4. A vacuum switch as claimed in claim 3, further comprising axially disposed spring biasing means associated with said bearing structure between said closure members for biasing said closure members with an axially applied force.

5. A vacuum switch adapted for high voltage, high current applications, comprising an evacuated envelope formed by an axially extending tubular bellows structure and a pair of closure plates formed of an electrical insulating material, each of said closure plates being secured to an end of said bellows structure with a vacuum-tight seal, so that said plates form a vacuum-tight enclosure within said bellows structure; a pair of contact members disposed within said bellows structure; a pair of axially disposed, electrically conductive rods mounted on and passing through said closure plates with vacuum-tight seals, said rods having said contact members mounted on the inner ends thereof, so that the outer ends thereof are adapted to form terminals for connecting the switch to an external circuit; a pair of axially disposed, concentrically arranged, cylindrical vapor shields surrounding said contact members and said rods, each of said shields having one end thereof mounted on a different one of said closure plates for axial movement therewith; and an axially extending bearing structure surrounding said bellows structure between said closure plates for interconnecting said closure plates to permit relative axial movement therebetween, whereby said contact members are adapted to be opened and closed by relative axial movement between said closure plates.

6. A vacuum switch as claimed in claim 5, wherein said bearing structure comprises a cylindrical support member having one end thereof fixedly mounted on one of said closure plates, the other of said closure plates being circular in shape and slidably supported within the other end of said support member, whereby said other closure plate is axially movable within said support member to open and close said contact members.

7. A vacuum switch as claimed in claim 5, wherein said bearing structure comprises a plurality of guide rods and means for fixedly mounting one end of each of said guide rods on one of said closure plates and slidably mounting the other of said closure plates on the other end of each rod, whereby said other closure plate is axially movable along said guide rods to open and close said contact members.

8. A vacuum switch as claimed in claim 7, wherein said mounting means includes a pair of end plates mounted on said closure plates for movement therewith.

9. A vacuum switch as claimed in claim 8, further

comprising a plurality of helical biasing springs, each of said springs being disposed about a different one of said guide rods between said end plates, whereby said springs are adapted to bias said end plates and closure plates with an axially applied force.

References Cited in the file of this patent

UNITED STATES PATENTS

1,875,765	Sherbius	Sept. 6, 1932
2,230,277	Volker et al.	Feb. 4, 1941
2,407,378	Miller et al.	Sept. 10, 1946
2,761,927	Szypulski	Sept. 4, 1956
2,794,101	Jennings	May 28, 1957
2,794,885	Jennings	June 4, 1957

FOREIGN PATENTS

138,997	Switzerland	Mar. 31, 1930
702,201	France	Jan. 19, 1931
615,965	Germany	July 17, 1935
663,422	Germany	Aug. 5, 1938