April 3, 1956 J. E. JENNINGS 2,740,867

VACUUM SWITCH

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Fig. 1

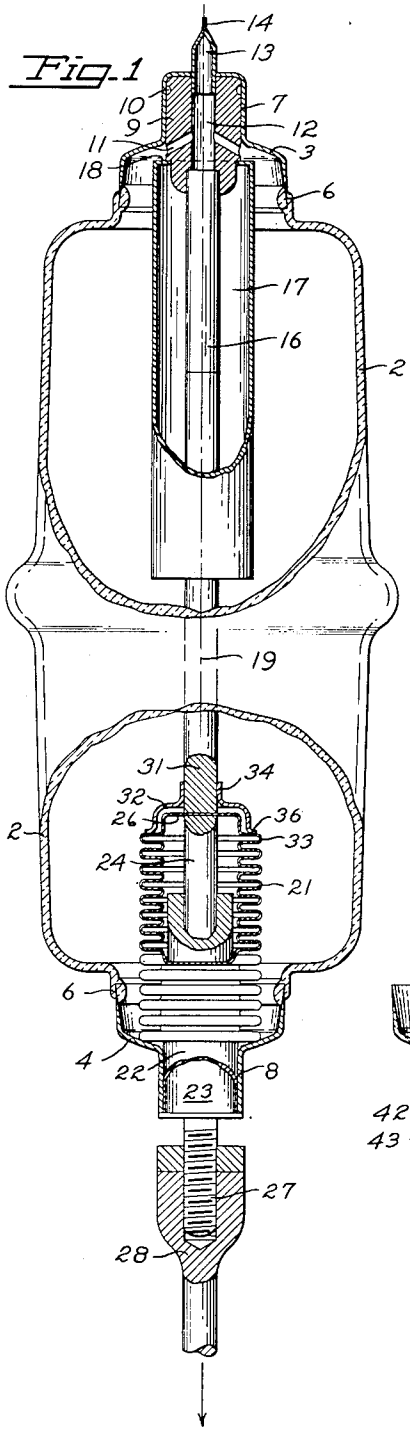


Fig. 2

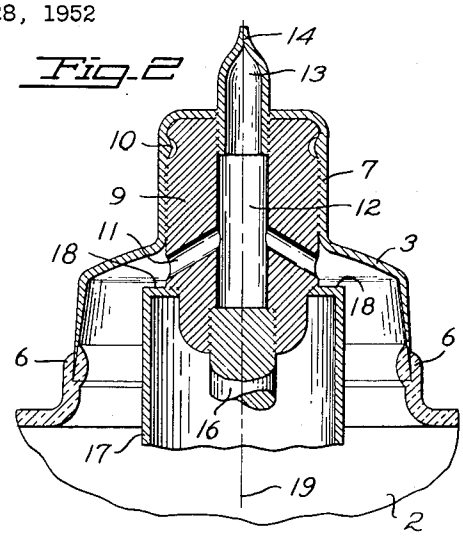


Fig. 3

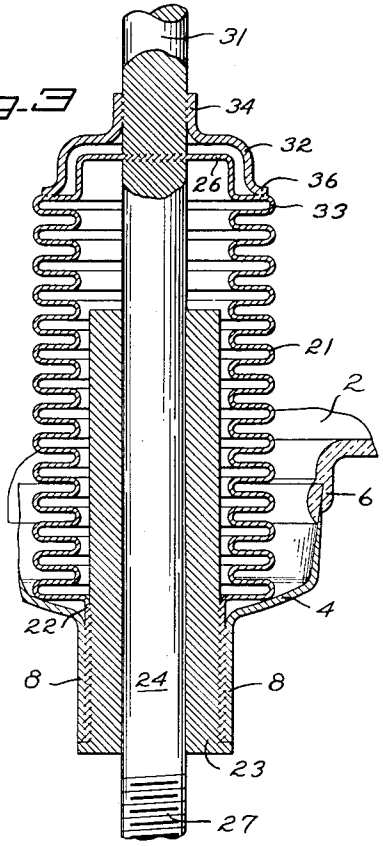
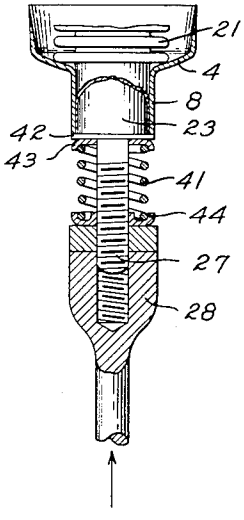


Fig. 4



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VACUUM SWITCH

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7 Claims. (Cl. 200—144)

My invention relates to vacuum switches but, more particularly, to novel terminal construction as well as to vapor condensing shields useful to prolong the life of such switches.

One of the objects of the invention is the provision of an electric switch, the contacts of which are enclosed within a vacuumized chamber so that arcing is reduced to a minimum.

Another object of the invention is the provision of a switch having contact points surrounded by a vapor condensing shield or baffle so that a build-up of conducting metallic film on the interior of the chamber is prevented.

Another object is the provision in a switch of the character described, of means for the rapid dissemination of heat evolved at the contact points.

Another object is the provision of a vacuumized switch in which the contact points may be engaged and held together resiliently in a normally closed position by pressure of the atmosphere; or, in the alternative, by the interposition of a spring to overbalance atmospheric pressure, the contact points may be resiliently held in normally open position, the actuating means or operator applying resilient pressure to close the contact points.

Still another object is the provision of a switch in which the degree of movement of parts to interrupt or establish the circuit is greatly reduced, with a corresponding increase in speed of operation.

The invention possesses other objects, some of which with the foregoing will be brought out in the following description of the invention. I do not limit myself to the showing made by the said description and the drawings, since I may adopt variant forms of the invention within the scope of the appended claims.

Referring to the drawings:

Fig. 1 is a plan view of my vacuum switch, portions being broken away to disclose the structure.

Figs. 2 and 3 are fragmentary half-sections respectively of the two ends of my switch, drawn to a scale twice that of Fig. 1.

Fig. 4 is a fragmentary view in horizontal section, showing an over-balancing spring applied to the structure of Fig. 1.

My vacuum switch comprises a vacuumized envelope in which metallic contact rods, one fixed and the other movable, are arranged in axial alignment. The interposition of a flexible metallic bellows between the mobile rod and the envelope wall permits operative movement of the mobile rod by means external to the envelope.

Since normal atmospheric pressure tends to expand the bellows into the envelope, the atmospheric pressure may be utilized to hold the contact points together in normally closed position, and to speedily close the gap between them upon release of separating pressure applied externally when the circuit through the switch is to be broken. In some uses, the contact points may be held in normally open position by interposition of a spring tensioned to overbalance atmospheric pressure.

The range of movement of the mobile contact rod is very small and extremely rapid. With only 1/8" of separation between the contact points, the stand-off value exceeds 100,000 volts. A switch such as illustrated in the drawings will safely handle voltages up to 50,000 and is capable of conducting continuously current volumes up to 50 amperes.

Although arcing between the contact points is at a minimum in the vacuumized envelope, some vaporization of the metal contact points occurs. If this vapor is allowed to condense and gradually build up on the inside surface of the envelope, it forms a conducting path between the inside terminals, thus shorting the contact points and seriously limiting the useful life of the unit. My invention provides a surface on which substantially all but a negligible amount of the vaporized metal, condenses without providing a conducting path around the contact rods, so that the useful life of the device is extended indefinitely.

One of the many applications of my switch is that of an overload relay in high voltage direct or alternating current uses. Thus it may operate as a protective instrument in high voltage rectifiers where an external overload or an internal flash back of a tube may occur; and because of its extremely rapid action in opening the circuit, it prevents other damage. Also in low voltage alternating current lines, my relay provides protection against overloads and short circuits.

Another use of my relay is in the broadcasting field where energy is to be shifted from one antenna to another, or to effect a change in directivity characteristics of an antenna. Since my relay is capable of withstanding much higher voltages than those at which they are operated, they may be used in "hot" condition; that is, while the station is in full operation. So far as I am aware this has never before been possible.

My switch finds a useful application in electrical circuits known as "interlocks" in which it is operated to interrupt the controlled circuit by linkage to the actuating element.

Perhaps the most important application of my switch, at least in the field of accident preventing, is its use where explosion due to flame or spark is a hazard. The vacuum tight envelope, enclosing the contact points, insures complete immunity.

In Fig. 1, I have shown a relay designed for use in a normally closed circuit where the pressure of the atmosphere tends to hold the contact rods together, and reestablishes contact after it has been broken. By proper designing of the end cap structure in which the contact rods are mounted, stresses may be distributed, so that when the contacts are closed, a balance of pressures on the end caps results, with a planned proportion of the atmospheric thrust upon the end cap structures carried by the engaged contact rods.

In some uses of my switch, where operation is planned in a normally open circuit, a coiled spring of sufficient strength to overbalance the atmospheric pressure may be interposed between the exterior end of the mobile contact rod and the end cap structure. The thrust of the operator is then inwardly to close the contacts. Fig. 4 suggests how this may be done.

In detail my vacuum switch comprises a glass shell **2**, closed at the ends with copper caps **3** and **4**, joined to the glass by the well known Housekeeper seal **6**. The caps constitute the external terminals of the switch and also provide lugs or bosses **7** and **8** respectively by which the instrument may conveniently be mounted in suitable clips or brackets, usually in a horizontal position.

The lug **7** of cap **3** is filled with a copper plug **9**, brazed in place by silver solder spreading from the groove **10**. The plug is provided with passages **11** leading from

inside the cap into the central passage 12 which leads into the copper tube 13, the inner end of which is brazed in the plug and adjacent cap wall. The tube is for use in exhausting the envelope and after that is completed, its free end 14 is pinched together so tightly as to effect a sealed closure.

Seated in the end of the plug and integrally united therewith by brazing is a relatively short metallic rod 16 preferably of tungsten, forming one of the contact points of the switch. Spaced from and surrounding the rod and extending well beyond its end is a cylindrical tube 17 preferably of copper, also mounted on the plug 9 by means of the inturned radial flange 18, brazed in a seat formed in the plug end. It is to be noted that all of this fixed end cap structure of terminal cap, plug, rod and tube are concentrically disposed about the long axis 19 of the structure, and integrally united into one continuous metallic body.

At the opposite end of the glass shell 2, the copper terminal cap 4 provides a mounting for the mobile contact rod and the bellows by which the envelope is closed and which permits movement of the rod without breaking the extremely high vacuum in the envelope.

The bellows 21 preferably of bronze of a 95–5 composition terminates at one end in a cylindrical sleeve 22, fitting snugly into the cylindrical base flange 8 of the cap 4. Fitting snugly into the side of the sleeve is a plug 23, extending well up into the bellows and providing a long journal bearing within which the mobile contact rod 24 preferably of stainless steel may slide. Base flange, sleeve and plug are brazed together so that the three are integrally united.

The bellows is closed at its inner end by the end wall 26, the rod 24 extending to the wall and being brazed to it with high temperature silver solder fusing at about 1000° C. The bellows folds are thus interposed between the rod 24 and the cap 4 and permit limited axial movement of the rod within its bearing plug without injury to the hermetic sealing of the envelope.

The outer end of the rod 24 is provided with threads 27 for connection to a link 28 forming part of an operating means which may be a solenoid mounted on the same bedplate which holds the bracket clips for the switch.

Because of the relative costs of steel and tungsten and for other reasons, the rod 24 is made of steel up to its union with the end wall of the bellows. To the outside of the bellows a tungsten rod 31 is brazed with high melting point silver solder in axial alignment with rod 24 so that the two are essentially one since they are integrally united through the bronze end wall of the bellows. The tungsten end of the rod extends into the open end of the tube 17, and into contact with the end of the fixed contact rod.

In order to connect the rod 24 more closely to the folds of the bellows and avoid a loss of motion because of flexibility in the end wall 26, a flanged nickel cap 23 is brazed over the end fold 33 of the bellows close to its periphery and also to the rod. Besides rigidly connecting the rod to the bellows, the cap facilitates the transmission of heat from the tungsten rod to the bellows and cap, and also provides a greater area for current flow. Since these brazing operations cannot all be accomplished at one time, the flange 34 of the cap is brazed to the rod with high melting point (about 1000° C.) silver solder, and the periphery 36 of the cap is brazed to the end fold 33 of the bellows with a silver solder melting at about 700° C., so that by performing this operation last, the earlier brazed connections are not imperiled.

Tungsten is preferred for the engaging ends of the contact rods because it has the highest melting point and the lowest vapor pressure of the refractory metals available, in addition to low electrical resistance and a low temperature gradient.

Like the fixed end structure, the mobile end of terminal cap, bellows, bearing plug, rod and stiffening cap are concentrically arranged about the long axis 19 and integrally united into one continuous metallic body. The sizes and relation of parts are such that when the envelope is fully evacuated, the two contact rods are pressed together with the full force of atmospheric pressure. Under operating conditions, and when energized, the solenoid (or other operator) pulls the rod 24 outwardly, perhaps ⅛", thus separating the contacting points of the two rods and breaking the circuit.

Since the atmospheric pressure against the inside of the bellows is substantially constant, the contact points are again engaged when the solenoid is deenergized, to reestablish the circuit through the contact rods. It is to be noted that by making the seals or end cap structures of the same diameter, atmospheric pressure inwardly against the seals may be equalized, so that in the open position of the switch unnecessary stresses in the end cap structures are avoided; and in the normally closed position, the inward pressures on the cap structures largely balance each other because of the intervening engaged contact rods.

The interruption of the circuit in the vacuumized envelope is attended with a minimum of arcing between the separating tungsten points of contact. This minimum is strongly influenced by the speed of separation; and use of a properly designed solenoid effects an almost instantaneous break and resultingly, there is a very minimum of sparking. However, it is impossible to wholly prevent all arcing and to the extent it occurs, tungsten is vaporized. Without a baffle or barrier means of some kind, the vaporized metal condenses on the inside surface of the glass shell, and builds up thereon a conducting layer which eventually shorts across the rods, and of course ruins the switch.

I prevent this result, although I cannot wholly prevent the cause, by surrounding the arcing points with the baffle tube 17. The tube extends a substantial distance on each side of the break point where arcing occurs; and the vaporized tungsten is caught by and deposited on the inside surface of the tube. Experiments have shown that with my baffle tube in place no significant quantity of metal vapor escapes from the tube into the interior of the envelope, and that no appreciable deposit on the interior surface of the glass envelope occurs to create a short circuiting film thereon.

In the fragmentary view of Fig. 4, I have shown the interposition of a spring 41 between the end 27 of the rod 24 and the adjacent external end 42 of the terminal cap. This is conveniently done by confining the spring between two flanged collars, one collar 43 loose on the rod and seated against the cap, and the other collar 44 threaded on the end 27 of the rod. By suitable proportioning of the parts, the collar 44 may be turned to adjust the tension of spring 41 to overbalance the atmospheric thrust on the bellows to the desired degree; and then the operator link turned up to also function as a lock nut against the collar. Of course a separate lock nut may be used to stabilize the adjustment of spring tension.

When a spring is interposed to overbalance atmospheric, the switch is normally open; and activation of the operator is necessary to close it. It will be observed that the switch unit is identical for both normally closed and normally open circuits, the latter use requiring only the external addition of the spring and collars to adapt it.

Copper is particularly suitable for the end cap structures since electric current is to be conducted, as well as the heat from the contact points carried to the external parts of the unit where it is dissipated into the air. The copper or bronze bellows which is in parallel with the rod 24 is a major conductor for both current and heat; and the copper baffle tube 17, while not directly in an electric circuit also functions in helping to dissipate heat generated at the contact points.

Tungsten is preferred for the contact rods or the major proportion thereof because it has the highest melting point and the lowest vapor pressure of available refractory metals, in addition to a low thermal and electrical resistance. The external portion **24** of the contact rod is of course exposed to the influence of the atmosphere with possibly a corrosive gas component. It may therefore be made of stainless steel or bronze.

I claim:

1. A vacuum switch comprising a vacuumized envelope having metal end caps constituting electrical terminals arranged on the long axis of the envelope and secured thereto in vacuum sealing relation, a contact rod fixed in one of the terminals and extending axially into the envelope, a mobile contact rod extending into the envelope and slidably journaled in the other terminal and aligned with and adjacent to the fixed rod, a bellows surrounding the mobile rod adjacent its bearing and interposed between the mobile rod and the adjacent terminal the ends of the bellows being integrally united with the mobile rod and the adjacent terminal respectively, and a baffle tube enclosing the contact rods on both sides of their adjacent ends and supported on one of the terminals.

2. A vacuum switch comprising a vacuumized envelope having metal end caps constituting terminals arranged on the long axis of the envelope, a contact rod fixed in one of the terminals and extending axially into the envelope, a mobile contact rod extending into the envelope and slidably journaled in the other terminal and aligned with and adjacent to the fixed rod, a bellows having an open end integrally united with such other terminal and surrounding the journal therein and having its other end closed and integrally united with the mobile rod, and a tube enclosing the contact rods on each side of and adjacent their opposed ends and being mounted on the terminal that supports the first named contact rod.

3. A vacuum switch comprising a vacuumized envelope having metal end caps constituting terminals arranged on the long axis of the envelope, a plug fixed in each terminal cap, a contact rod fixed in one of the plugs, a baffle tube surrounding and extending past the end of the contact rod and being fixed to said last named plug, a mobile contact rod slidably journaled in the other plug and aligned with the fixed rod within the tube, and a bellows surrounding the mobile rod adjacent its bearing and integrally united with the adjacent terminal and having its other end integrally united with the mobile rod.

4. A vacuum switch comprising a vacuumized envelope having metal end caps constituting terminals arranged on the long axis of the envelope, a plug fixed on each terminal cap, a contact rod fixed in one of the plugs, a tube surrounding and extending past the end of the contact rod and fixed on the same plug, a mobile contact rod slidably journaled in the other plug and aligned with the fixed rod within the tube, a bellows surrounding the mobile rod adjacent its bearing and integrally united with the adjacent terminal and having its other end integrally united with the mobile rod, an exhaust tube extending outwardly from the fixed rod terminal cap and plug, and a passage in the plug connecting the exhaust tube to the inside of the envelope.

5. A vacuum switch comprising a vacuumized envelope having metal end caps constituting terminals arranged on the long axis of the envelope, a contact rod fixed in one of the terminals and extending axially into the envelope, a mobile contact rod extending into the envelope and slidably journaled in the other terminal and aligned with and adjacent to the fixed rod, a bellows having an open end integrally united with such other terminal and surrounding the journal therein and having its other end closed and integrally united with the mobile rod by means of a rigid flanged cap fixed to the mobile rod and to the closed end of the bellows adjacent its outer edge, and a tube enclosing the contact rods on each side of their adjacent ends and mounted on one of said terminals.

6. A vacuum switch comprising a vacuumized generally cylindrical envelope having its opposite ends closed by terminal caps of the same external area and arranged in the long axis of the envelope, a contact rod fixed in one of the terminal caps and extending into the envelope, a mobile contact rod extending into the envelope and slidably journaled in the other terminal cap and aligned with the fixed rod, vacuum tight flexible means interposed between the mobile contact rod and its associated terminal cap and allowing limited axial movement of the mobile rod into and out of the envelope, and a tube enclosing the contact rods on each side of their adjacent ends and mounted on one of the terminal caps.

7. A vacuum switch comprising a vacuumized envelope having metal end caps constituting terminals arranged on the long axis of the envelope, a metallic bellows fixed at one end on one of the terminals and extending axially into the envelope, a plug fixed on the last named terminal within the bellows, a mobile rod slidably mounted in the plug and fixed to the mobile end of the bellows, an extension of said rod within the envelope beyond the mobile end of the bellows, and a fixed contact rod mounted on the other terminal and with which the mobile contact rod may be engaged.

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