

June 3, 1958

W. G. GUSTAFSON ET AL
MERCURY SWITCHES

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3 Sheets-Sheet 1

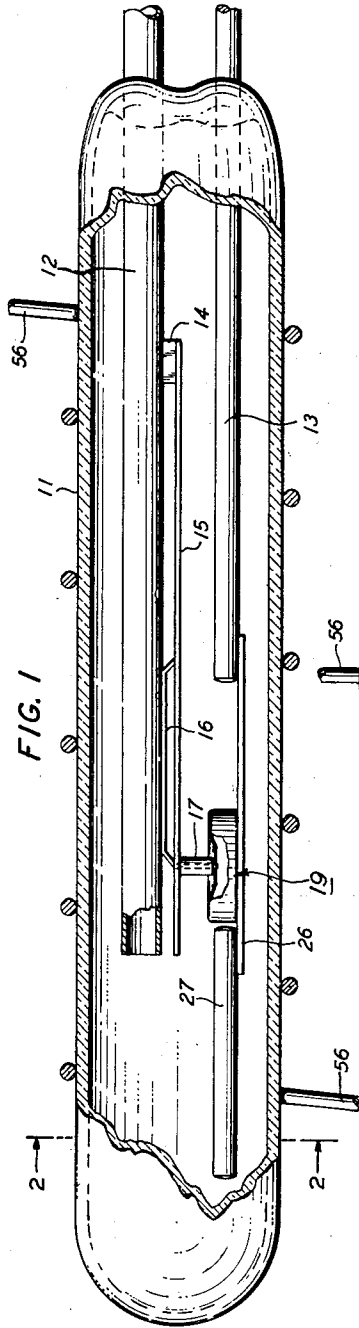


FIG. 1

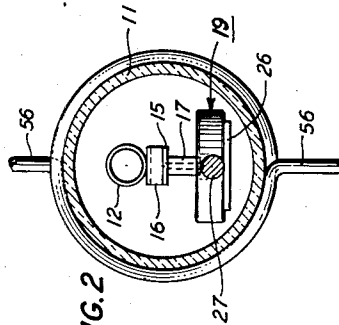


FIG. 2

FIG. 5

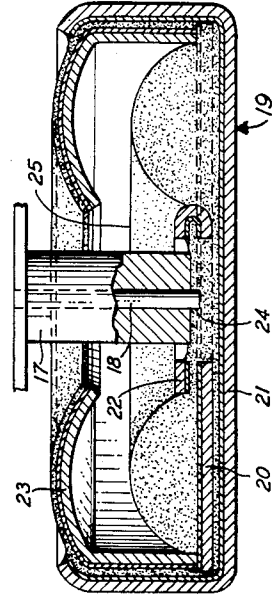
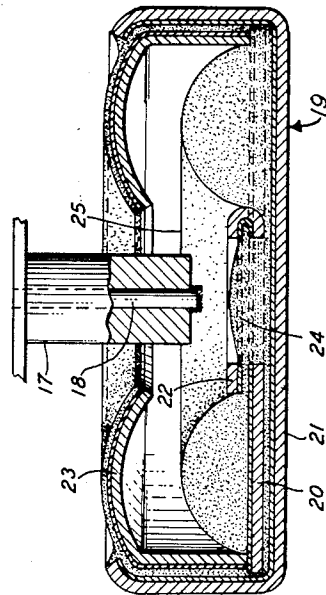


FIG. 4



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FIG. 8

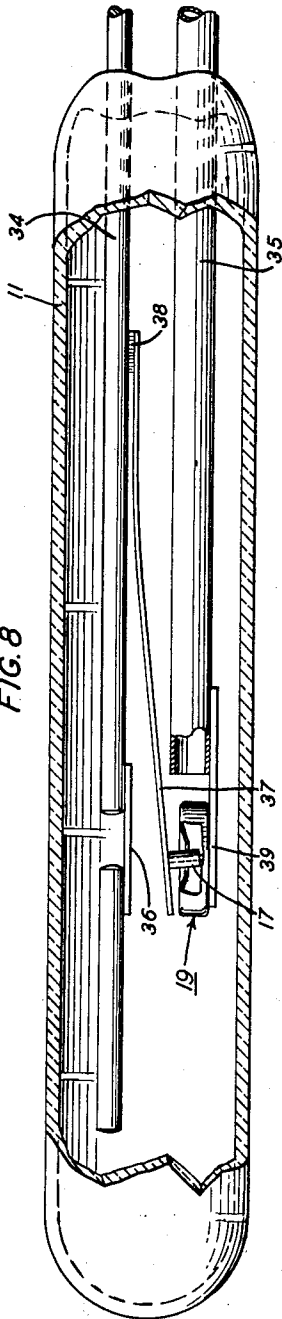


FIG. 9

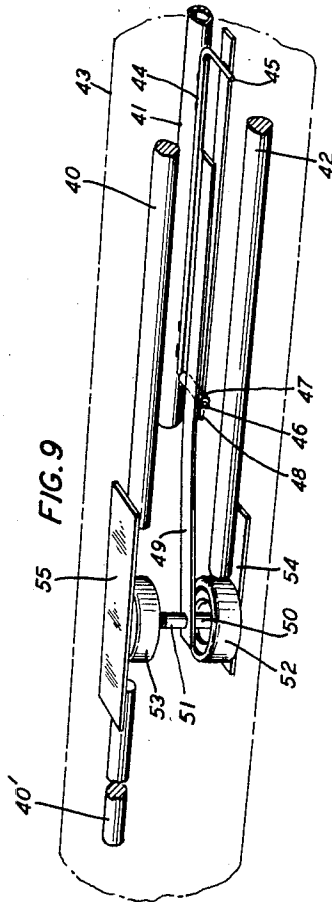


FIG. 3

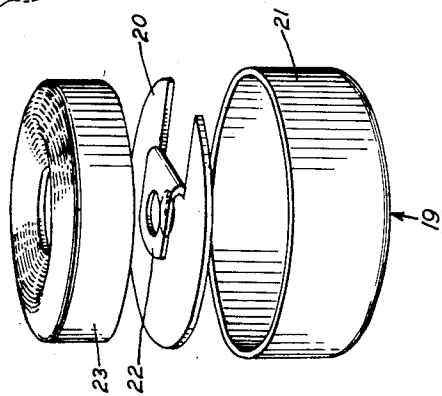
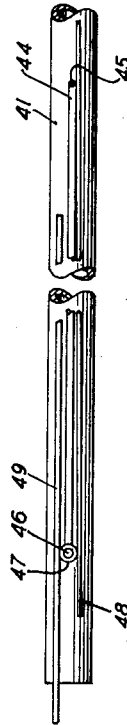


FIG. 10



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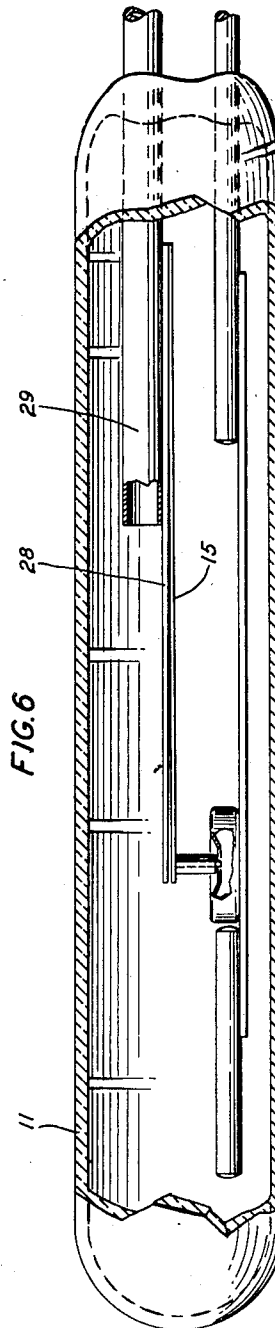
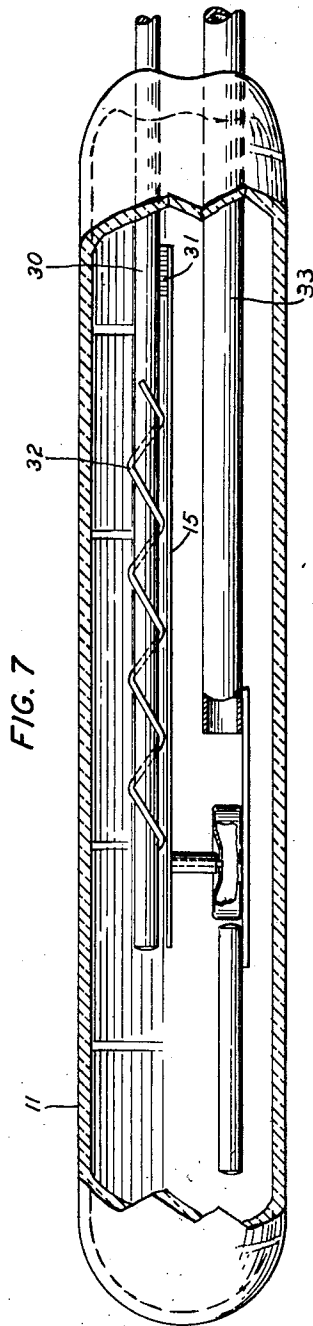
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3 Sheets-Sheet 3



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2,837,612

MERCURY SWITCHES

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10 Claims. (Cl. 200—87)

This invention relates to circuit controlling devices and more particularly to such devices of the type commonly referred to as mercury switches.

Mercury switches comprise, in general, a pair of contacts and a body of mercury, one or both of the contacts or the mercury being movable to establish a conductive path through these three elements or, conversely, to open such path. Heretofore, primarily because of the fluid character of mercury at the temperatures at which the switches usually are utilized, it was necessary that the switches be mounted or operated in a particular position. Also, in such devices of the class wherein one or both of the contacts are movable to effect closure or opening of the conductive path or circuit, relatively large power expenditure has been required to effect operation. Further, in devices of this class, chatter upon making or breaking has been a problem. In addition, and this has been of special moment in cases where the switches have been employed to control circuits for inductive loads, the pulse voltage developed upon breaking of the circuit has been unduly large.

One general object of this invention is to improve circuit controlling devices of the type wherein a body of mercury is utilized as a portion of the conductive path to be closed or broken.

More specifically, objects of this invention include to enable mounting of mercury switches for operation in any position, to increase the sensitivity of and reduce the power requisite for operation of such switches, to minimize chatter and to reduce the voltages developed in circuits including an inductive load, upon opening of the circuit.

Additional objects of this invention are to facilitate the fabrication of such switches, to simplify the structure thereof and to reduce the size of circuit controlling devices capable of performing multiple functions, for example, make and break of plural circuits or transfer.

In one illustrative embodiment of this invention, a circuit controlling device comprises a pair of terminals, a body of mercury coupled to one of the terminals and an armature connected to the other terminal and actuable to engage with or disengage from the mercury body.

In accordance with one feature of this invention, the mercury body is confined or localized within a container having therein an aperture through which a contact attached to the armature may pass, the container being constructed and arranged so that irrespective of the position of the device the mercury remains in operative relation with respect to the contact.

More specifically, in accordance with this feature of the invention, the inner wall of the housing includes a portion opposite the contact, which is wet readily by mercury, and the remaining portions are of a material which does not wet readily. In effect, the mercury adheres to the readily wettable portion and is not displaceable easily by jarring or even inversion of the container.

In accordance with another feature of this invention, the aforementioned wettable portion has thereadjacent

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an annular member adapted to accommodate the contact and defining a restricted passageway within the container. The contact, upon actuation to engage the mercury, forces some of the latter through the passageway, whereby a resistive damping of the armature-contact motion is realized.

In accordance with still another feature of this invention, vibrational energy dissipative elements are provided for engaging the armature when it operates to disengage the contact from the mercury.

In accordance with a further feature of this invention, the armature and container are mounted respectively by a pair of substantially parallel magnetic members, the armature being positioned between the two members and having one end fixed to one member and its other end free. Actuation of the armature is effected, for example by a signal coil encompassing both the members, by magnetization of the members such that one attracts and the other repels the armature, whereby high sensitivity is realized.

In accordance with a still further feature of this invention, the contact and container are correlated to provide a small and constant gap therebetween during actuation of the contact, whereby the voltage induced with an inductive load in the circuit being controlled is minimized.

In accordance with another feature of this invention, the contact comprises a portion readily wet by mercury, extending from a body which is not readily wet, the extending portion being at the end toward the body of mercury. Thus, at least after a single operation, whereby the extending portion is wet by mercury, on a make the initial contact is between mercury and mercury, and hence a quick and low resistance closure is attained. Because of the non-wetting character of the contact body, substantial resistance to immersion of the contact is developed. Hence, a stop is provided upon motion of the contact. Further, because of the non-wetting characteristic noted, the force necessary to produce a break, i. e., to disengage the contact from the mercury, is small.

The invention may be embodied in switches for performing a variety of different functions, such as to make or break circuits, to control a plurality of circuits concomitantly or to effect transfer between circuits. Further, one or more magnets may be associated with the armature actuating system to provide polarized operation, or the armature may be operated by electrostatic means.

The invention and the features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings, in which:

Fig. 1 is a longitudinal view of a mercury switch with the envelope broken away to illustrate one embodiment of the invention;

Fig. 2 is a sectional view taken along the line 2—2 of the switch in Fig. 1;

Fig. 3 is an exploded perspective view showing the assembly of a container for the body of mercury;

Fig. 4 is a cross sectioned view of the mercury container when the switch is in a fully open position;

Fig. 5 is a cross sectioned view of the mercury container when the switch is fully closed;

Figs. 6 and 7 comprise longitudinal views of two modifications of the device with the envelopes thereof broken away;

Fig. 8 is a longitudinal view of another modification of the device with the armature in a normally closed position;

Fig. 9 is a perspective view of a transfer switch embodying the features of the invention; and

Fig. 10 is an enlarged side view of the tubular electrode shown in Fig. 9, illustrating the means used to support the armature.

Referring to Fig. 1 of the drawings, there is shown a preferred embodiment of the invention. The elements of the mercury switch are enclosed in an envelope 11 made of vitreous material such as glass. In order to suppress contact arcing, the envelope may be filled with an inert gas such as hydrogen, although this is not essential for operation of the switch. Inserted in the envelope 11 are two electrodes 12 and 13 which comprise the contact terminals. These electrodes may be formed of any suitable material of high electrical conductivity, but inasmuch as the switch is operated by an external magnetic force it is important that the electrodes be made of magnetic material. In the specific embodiment shown in Fig. 1, the electrode 12 is tubular in shape, thereby facilitating fabrication since both the mercury and the inert gas may be inserted into the envelope through this tube.

Attached to the bottom of the electrode 12 is a supporting member 14 which is used to hold the armature 15 in place. These elements may be spot welded together so that a continuous current carrying path is formed from the armature 15 to the electrode 12. To insure maximum operating efficiency, the armature should not extend beyond the end of the electrode. It is preferred to make the armature from a thin Permalloy reed so that a maximum sensitivity may be attained. The armature is biased upward so that in its normal position it rests against the damping spring 16 in such a manner that during contact breaks the deleterious effects of chatter are reduced to a minimum. The damping spring 16 is made of a highly resilient material and is spot welded to the electrode 12 so that the vibration of the armature 15 is reduced as much as possible.

Attached to the armature 15 is a contact pin 17, which is illustrated in detail in Figs. 4 and 5. The pin is formed of a material not wettable by mercury and has a current-carrying shaft 18 along its axis that is mercury wettable and slightly longer than the contact pin 17, so that it protrudes from the bottom of the pin. This configuration has several advantages. The mercury-wettable shaft 18 retains a thin film of mercury thereon which provides a mercury to mercury contact when the armature 15 is energized, whereby a quick and low resistance closure is attained. By making the contact pin 17 non-wettable, upon closure, the natural resistance of the contact pin to immersion in mercury prevents the shaft 18 from striking the bottom of the mercury container 19, thus avoiding all solid contact and greatly increasing the life of the switch. Furthermore, when the contact pin disengages there is very little surface tension tending to hold it immersed in the mercury, and consequently the sensitivity is greatly increased. A convenient method of fabricating the contact pin 17 is to cut it from a chromium plated tungsten wire. The chromium plating should be sufficiently thick to provide a large cross sectional area ratio between the contact pin 17 and the shaft 18, so that the above advantages may be fully realized. The chromium is etched until the tungsten protrudes from the lower end of the contact pin. Since tungsten wets readily with mercury while chromium does not, the advantages of a mercury to mercury contact are retained without affecting the sensitivity.

The assembly of a mercury container 19 is illustrated in Fig. 3. A centrally apertured circular plate 20 is inserted in the base 21 so that there is a slight clearance between the plate and the base. A portion of the plate 20 is cut and bent over to form an annular member 22, which stabilizes the mercury surface at the center of the container where the apertures are aligned and provides armature damping as will subsequently be described. A cover 23 fits inside the base 21 and has an aperture in the top which permits the contact pin 17 to enter the container 19 and make contact with the mercury. The apertures

in the cover 23, the plate 20 and the annular member 22 are in substantial alignment. The tolerances between the cover aperture, the annular member 22 and the contact pin may be quite liberal but should be small enough to prevent any excess mercury from escaping from the container.

The elements of the mercury container 19 are made of a material that will not amalgamate with mercury and are plated on one side with platinum or other mercury wettable substance. It is of no particular concern whether the container material is magnetic or non-magnetic. However, in embodying the invention in specific switch designs there may be advantages gained in using one material or the other. The location of these wettable surfaces is illustrated in Figs. 4 and 5 and is of prime importance. The interior of the base 21, the exterior of the cover 23, the upper surface of the plate 20 and the lower surface of the annular member 22 are all mercury wettable, so that the mercury within the container will adhere to these surfaces. When a drop of mercury hits the top of the container 19, capillary forces pull it inside, and the surface tension of the mercury makes it take the shape shown in Figs. 4 and 5. The mercury surface 24 in the center of the container 19 is confined between the annular member 22 and the plate 20, so that it is quite stable and its position can be controlled within narrow limits. The level of the surface 24 would also change very little with any change in the volume of the mercury pool 25 inside the container, because of the confining nature of the mercury wettable surfaces on the annular member 22 and the plate 20. Besides forming the mercury surface 24, the annular member 22 provides a small gap through which a portion of the mercury must go when hit by the contact pin 17. Because of the natural adhesion of the mercury to the wettable surfaces, a mechanical resistance, or energy loss, is introduced in the circuit which damps the contact pin 17 and hence the armature 15, thereby preventing chatter when the switch closes. The mercury pool 25 acts as a reservoir for the mercury surface 24, and because of the particular configuration of the container 19 it is very difficult to shake the mercury out, either by jarring or even by inversion of the switch. Consequently, the switch may be mounted for operation in any position. During long continuous operation, a certain amount of the mercury may vaporize inside the envelope 11. By plating the upper surface of the cover 23 with a mercury wettable material, the vaporized mercury will condense on this surface, and capillary forces will cause it to return to the interior of the container 19 through the passageway between the exterior of the cover 23 and the interior of the base 21.

Referring again to Fig. 1, the mercury container 19 is supported by a thin non-magnetic plate 26 which is attached to the electrode 13. The other end of the plate supports a magnetic wire 27, so that a non-magnetic gap is provided between the wire and the electrode. The gap is partly filled by the mercury container 19, thereby completing the magnetic circuit.

Other details will be understood from the following description of the mode of operation of the device.

When a magnetic field is applied to the switch of Fig. 1, such as by an energizing winding 56 enclosing all or part of the envelope 11, there is a repulsive force between the electrode 12 and the armature 15. At the same time, there is a force of attraction between the armature 15 and the wire 27. By making the mercury container 19 of magnetic material and placing it in close proximity to the end of the electrode 13, so that there is a small non-magnetic gap between these two elements, the curved flux pattern will provide an additional attractive force that will practically double the sensitivity. However, this is not essential for successful operation of the switch. The combined forces result in a force which is roughly linear with the travel of the contact pin 17.

As the contact pin 17 makes contact with the mercury

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surface 24, a small amount of mercury is forced from underneath the annular member 22, thus providing a resistive force that will eliminate chatter on contact makes, as previously described. The pin 17 and the mercury container 19 are correlated to provide a small and constant gap therebetween, thereby minimizing the peak voltage induced in the circuit. Because of the wetting characteristics of the annular member 22, the natural resistance of the mercury will prevent the pin 17 from striking the container base 21, except when a large magnetic force is applied. This mechanical contact may be prevented entirely by reducing the cross sectional area of the magnetic components until they become magnetically saturated, after which time the amount of external magnetic force applied will have little effect on the distance traveled by the contact pin 17.

When the magnetizing current is removed, the natural resiliency of the armature 15 will move the contact pin 17 out of engagement with the mercury surface 24, thus opening the circuit. As the armature returns to its normal position, it strikes the damping spring 16, thereby reducing vibration.

Fig. 6 illustrates another embodiment of the invention where in a different means for damping the armature 15 has been provided. In this modification the various parts of the structure are substantially similar to those previously described with the exception of a flat spring 28, which has been substituted for the damping spring 16 shown in Fig. 1. The flat spring is attached to an electrode 29, which is similar to the electrode 12 (Fig. 1) except that it does not extend as far into the envelope 11. In its normal position the armature 15 is in contact with the flat spring 28, and since the spring 28 is made of a magnetic material the sensitivity of the switch is improved. When the armature 15 returns to normal after the magnetizing current is removed, any vibrations are communicated to the flat spring 28, so that they are effectively damped. This type of spring is particularly useful in circuits requiring extremely high sensitivity and freedom from chatter.

Another embodiment of the invention is shown in Fig. 7. The basic structure is retained except for the means used for damping the vibrations of the armature 15. Attached to the wire electrode 30 is a supporting member 31 to which the armature 15 is fastened. A fine wire coil 32 is wrapped around the electrode 30 and is secured thereto at each end by means of a spot weld or other known method of attachment. As the armature 15 returns to normal, it strikes the coil 32 so that the vibrational energy is dissipated and damping is attained. The electrode 33 is made tubular in shape to facilitate assembly.

Referring to Fig. 8, there is shown a normally closed mercury switch embodying the features of the invention. Enclosed within the envelope 11 are two electrodes 34 and 35. The upper electrode 34 comprises a wire of conductive material with a non-magnetic gap located directly above the contact pin 17. The two portions of the electrode 34 are connected by a non-magnetic plate 36, which has a certain amount of flexibility so that the vibrations of the armature 37 may be reduced when the switch is opened. The armature is attached to the bottom of the electrode 34 by means of the supporting member 38 and is biased in a downward position so that the contact pin 17 attached to its free end is in engagement with the mercury in the container 19. The contact pin and the container are illustrated in Figs. 4 and 5 and conform to the previous description. The mercury container is supported by a magnetic plate 39 which is attached to the end of the tubular electrode 35, thus maintaining continuity in the magnetic circuit.

When a magnetizing current is applied to a coil encompassing the envelope 11 (see Fig. 1), there is a repulsive force between the lower assembly (the container 19, the plate 39 and the electrode 35) and the armature 37.

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At the same time, there is an attractive force between the armature 37 and the two segments of the electrode 34. These forces combine to raise the armature, thereby disengaging the contact pin 17 from the mercury in the container 19. It will be noted that the magnitude of these forces necessary to actuate the switch is very small, and consequently the device is highly sensitive in operation. When the magnetizing current is removed, the natural resiliency of the armature 37 returns it to its normal position, thereby causing the contact pin 17 to engage with the mercury in the container 19 to close the circuit.

In Fig. 9 there is shown a mercury switch embodying the features of the invention designed to effect transfer between circuits. Three electrodes 40, 41 and 42 are enclosed within the envelope 43, which is filled with an inert gas. One of the electrodes may be made tubular in shape so that the inert gas and the mercury can easily be inserted into the envelope. A wire support 44 is attached lengthwise along the electrode 41 and has two right angle projections 45 and 46, one of which is encompassed by a roller 47 which is free to rotate thereon. Attached to the lower portions of the roller 47 and the projection 45 is a flat spring 48, which is held in place by spot welding or other suitable means. An armature 49 is fastened to the roller 47 and pivots about the projection 46. It is so positioned that in its actuated position (left end moved upward) the right end thereof rests against the flat spring 48. The resiliency of the spring 48 thereby provides an effective method of armature damping that will reduce chatter. The positioning of the above-described means for supporting the armature 49 is illustrated in detail in Fig. 10.

Attached to opposite sides of the left end of the armature 49 are two axially aligned contact pins 50 and 51. These pins are identical with those illustrated in Figs. 4 and 5 and conform to the previous description. A mercury container 52 is supported by a magnetic plate 54, which should not extend beyond the tip of the armature 49 in order to insure maximum sensitivity and operating efficiency. Otherwise, there would be small attractive forces built up between the left end of the plate 54 and the armature 49 which would tend to hamper proper operation of the switch. A mercury container 53 is supported by a non-magnetic plate 55, which is secured to the electrode 40 in such a manner that the outer segment 40' of the electrode is supported thereby. The mercury containers 52 and 53 are positioned so that they may be engaged by the contact pins 50 and 51, respectively, and are of a construction identical with that hereinbefore described. The various components of the above-described transfer switch are held together by spot welding or other suitable means of attachment.

In its normal position (as shown) the armature 49 is positioned on the roller 47 so that the contact pin 50 is in engagement with the mercury in the container 52, thus forming a continuous current carrying path from the electrode 41 to the electrode 42. When an external magnetizing current is applied to a coil encompassing the electrode 43 (see Fig. 1), there is a repulsive force between the armature 49 and the magnetic plate 54. Simultaneously, there is a force of attraction between the armature 49 and the two segments of the electrode 40. These combined forces cause the armature to move toward the mercury container 53, disengaging the contact pin 50 from the mercury container 52 and engaging the contact pin 51 with the mercury container 53. Hence the circuit is transferred from the electrode 42 to the electrode 40, forming a continuous current carrying path from the electrode 41 to the electrode 40. As the switch is energized, the opposite (right) end of the armature 49 strikes the flat spring 48 so that any armature vibrations are minimized.

When the magnetizing current is released, the torsional force of the flat spring 48 acting on the roller 47 causes

the armature 49 to rotate in a counterclockwise direction about the projection 46. Hence, the contact pin 51 disengages from the mercury container 53 and the contact pin 50 comes into contact with the mercury container 52, thereby returning the switch to its normal position.

It is apparent that the various modifications of the component parts of the switch are, in many instances, interchangeable with each other, and that certain of the mechanical details shown may be modified without departing from the scope and spirit of the invention as defined in the appended claims.

What is claimed is:

1. In a mercury switch, a container having an aperture therein, an annular member positioned in said container, a body of mercury in said container, a contact in line with said aperture and with said annular member, and means for moving said contact into and out of engagement with said mercury.

2. In a mercury switch, a container, a body of mercury in said container, a contact positioned in proximity to said container, said contact having a body portion of material for which mercury has low affinity and having also, at the end thereof nearest said container, a restricted portion for which mercury has high affinity, and means for moving said contact into and out of engagement with said mercury.

3. In a mercury switch, a container having an aperture therein, the inner base wall of said container being of a material for which mercury has high affinity and the remaining inner walls of said container being of a material for which mercury has low affinity, a body of mercury in said container, a contact in line with said aperture, and means for moving said contact into and out of engagement with said mercury.

4. In a mercury switch, a container having an aperture therein, the inner base wall of said container being of a material for which mercury has high affinity and the remaining inner walls of said container being of a material for which mercury has low affinity, an annular member positioned in said container, a body of mercury in said container, a contact in line with said aperture and with said annular member, and means for moving said contact into and out of engagement with said mercury.

5. In a mercury switch, a container having an aperture therein, the inner base wall of said container being of a material for which mercury has high affinity and the remaining inner walls of said container being of a material for which mercury has low affinity, an annular member positioned in said container, the surface of said annular member adjacent to the base of said container being of a material for which mercury has high affinity, a body of mercury in said container, a contact in line with said aperture and with said annular member, and means for moving said contact into and out of engagement with said mercury.

6. A switch comprising a container having a cup-shaped portion and a cover portion, said cover portion having an aperture therein, the inner base wall of said container being of a material for which mercury has high affinity and the remaining inner walls of said container being of a material for which mercury has low affinity, a body of mercury in said container, a contact in line with said aperture, and means for moving said contact into and out of engagement with said mercury.

7. A switch comprising a container having a cup-shaped portion and a cover portion, said cover portion having an aperture therein, the inner base wall of said container being of a material for which mercury has high affinity and the remaining inner walls of said container being of a material for which mercury has low affinity, a body of mercury in said container, a contact in line with said aperture and having a body portion of material for which mercury has low affinity and having also at the

end thereof nearest said container a restricted portion for which mercury has high affinity, and means for moving said contact into and out of engagement with said mercury.

8. A switch comprising a container having a cup-shaped portion and a cover portion, said cover portion having an aperture therein, the inner base wall of said container being of a material for which mercury has high affinity and the remaining inner walls of said container being of a material for which mercury has low affinity, an annular member positioned in said container, the surface of said annular member adjacent to said inner base wall being of a material for which mercury has high affinity, a body of mercury in said container, a contact in line with said aperture and with said annular member, and means for moving said contact into and out of engagement with said mercury.

9. In a mercury switch, a container having a cup-shaped portion and a cover portion, said cover portion having an aperture therein, the inner base wall of said container being of a material for which mercury has high affinity and the remaining inner walls of said container being of a material for which mercury has low affinity, an annular member overlying said inner base wall and spaced therefrom to define a restricted aperture therewith, the surface of said annular member adjacent to said inner base wall being of material for which mercury has high affinity, a body of mercury in said container, a contact in line with said cover portion aperture and with said annular member and having a body portion of material for which mercury has low affinity and having also, at the end thereof nearest said container, a restricted portion for which mercury has high affinity, and means for moving said contact into and out of engagement with said mercury.

10. In a mercury switch, a switch envelope, a container enclosed in said envelope and having a cup-shaped portion and a cover portion, said cover portion having an aperture therein, the inner base wall of said container and the exterior of said cover portion being of a material for which mercury has high affinity and the remaining inner walls of said container being of a material for which mercury has low affinity, an annular member overlying said inner base wall and spaced therefrom to define a restricted aperture therewith, the surface of said annular member adjacent to said inner base wall being of a material for which mercury has high affinity, a body of mercury in said container, a contact in line with said cover portion aperture and said annular member and having a body portion of material for which mercury has low affinity and having also, at the end thereof nearest said container, a restricted portion for which mercury has high affinity, a contact arm supporting said contact, a first electrode connected to said contact arm, a second electrode connected to said container, and means for moving said contact arm whereby said contact connected therewith is moved into and out of engagement with said mercury.

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