

Nov. 6, 1956

J. T. L. BROWN ET AL
MERCURY CONTACT SWITCH

2,769,875

Filed Sept. 25, 1953

2 Sheets-Sheet 1

FIG. 1

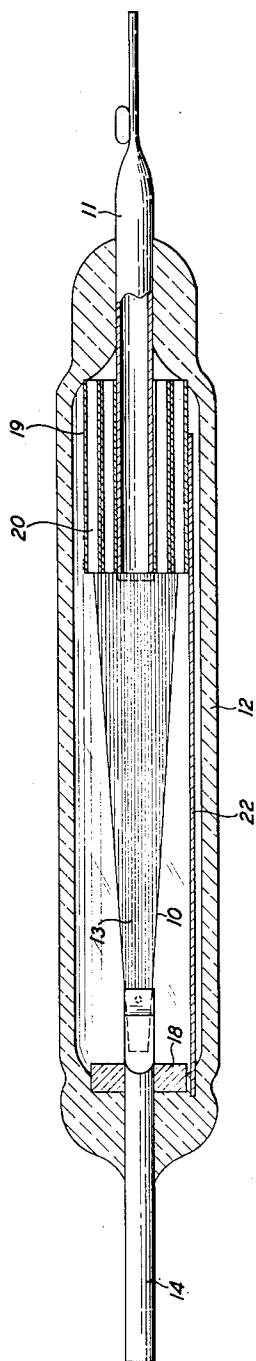
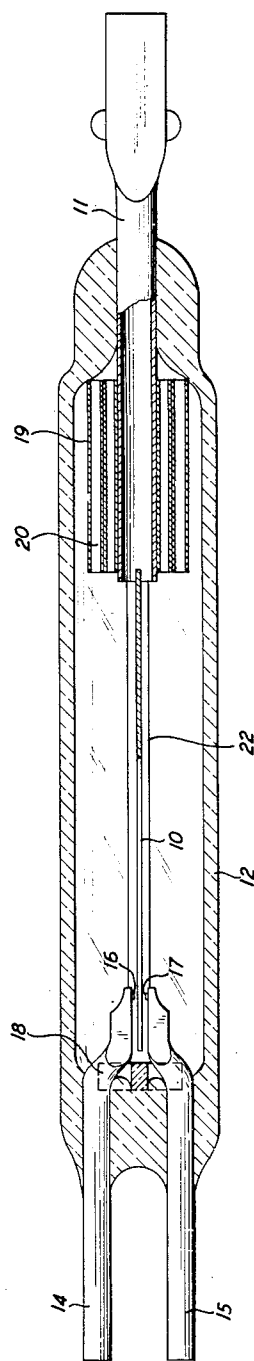


FIG. 2



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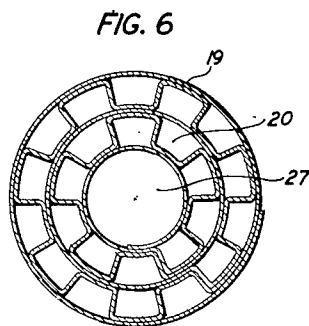
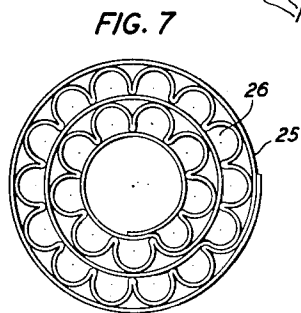
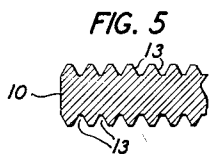
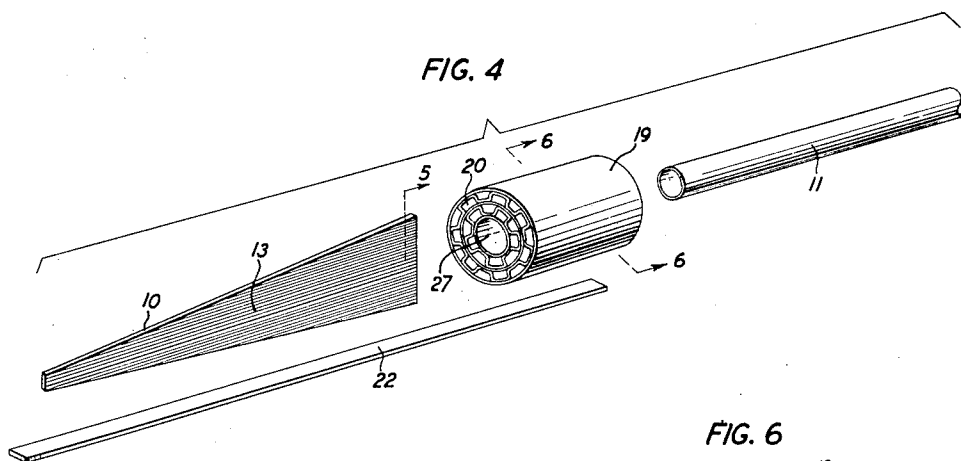
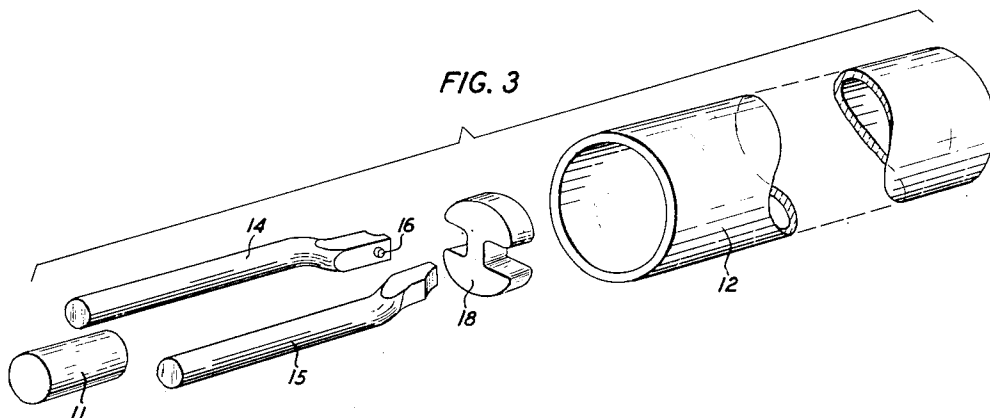
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MERCURY CONTACT SWITCH

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19 Claims. (Cl. 200—112)

This invention relates to relays and more particularly to polar mercury contact relays or switches.

Heretofore in the prior mercury contact relay art, exemplified by our Patent 2,609,464 which issued September 2, 1952, mercury in a pool at the bottom of the relay or switch is fed through a groove or grooves in the armature to the contact area. When the contact elements are separated, a filament of mercury is formed which breaks at two points allowing a small drop of mercury to fall into the pool below. The utilization of a mercury pool requires the vertical or near vertical positioning of the relay. For angles greater than 30 degrees from vertical, or for external accelerations or shocks producing an equivalent effect, the mercury tends to short-circuit the contacts by filling the space therebetween. The mercury pool under such external accelerations, vibrations or shocks moves about to interfere with successful operation of the switch.

It is therefore an object of the present invention to provide novel mercury contact devices which will operate equally well in any position.

Another object of the present invention is to provide novel mercury contact devices having mercury pools that are substantially restrained under external accelerations. These objects are accomplished by utilizing a capillary reservoir retaining the mercury pool to which the mercury is returned when the contact elements are separated. A sponge was provided in the prior mercury contact relay art as shown in the Patent 2,445,406 which issued to C. E. Pollard, Jr. on July 20, 1948, to provide for greater positioning flexibility. The sponge, however, had to be maintained at a lower position than the contact area so that the drop of mercury from the contact area formed when the contact elements were separated could return to the sponge.

A feature therefore, of the present invention relates to a novel mercury contact relay having a reservoir and drain element, with the drain element returning the mercury from the contact area to the reservoir to allow for horizontal positioning of the relay.

Still another feature pertains to a novel mercury contact relay having a reservoir and drain element whereby the relay can be mounted and successfully operated having the reservoir positioned above the contact area.

In the vertical switch or relay with the contact area above the mercury pool, the mercury in the region of the contact elements is under a negative pressure or head which is equivalent to a suction. The negative head at the contact elements determines a number of operating characteristics and constructional features such as the length of time for the contacts to separate, the thickness of the mercury cushions at the contacts, the allowable proximity of the pole-pieces while insuring the breaking of the mercury filament when the contacts separate, etc. In the prior art switch utilizing a sponge, the negative head at the contacts varies with the amount of mercury in the sponge so that the negative head varies during the

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operation of the switch and the provision of a predetermined negative head is difficult.

Still another feature of the present invention, therefore, pertains to a novel mercury contact switch having a constant negative head at the contacts.

A further feature of the present invention relates to a novel polar mercury contact device which can be readily manufactured to have a predetermined negative head at the contacts.

This invention overcomes the difficulties existing in the prior art and achieves the above objects by providing for a glass enclosed magnetically operated armature with the magnets extended radially from pole-pieces at one side of the relay. The armature is a flat tapered reed which is mounted on a tubular stem extending through the glass on the other side of the relay. The armature is operated symmetrically between contacts on the two fixed pole-pieces. The armature and contacts are wet with mercury, which is supplied to the contact surfaces through capillary grooves on the surface of the armature from a capillary reservoir. The reservoir is supported on the tubular stem which supports the armature and comprises a plurality of capillary tubes which contain the mercury. The negative head at the contacts is dependent upon the diameter of the tubes in the reservoir and not upon the amount of mercury therein as long as it is not completely full. A drain or wick is provided along the inside and bottom of the glass from the contact area to the reservoir to return the mercury thereto when the contacts are operated.

Still another feature of the present invention, therefore, relates to a novel mercury contact switch having a capillary reservoir with the capillaries being of constant diameter.

Still another feature of the present invention relates to a novel capillary reservoir for mercury contact relays having a plurality of tubes of constant cross-section.

Further objects, features and advantages will become apparent to those skilled in the art upon consideration of the following description taken in conjunction with the drawings wherein:

Fig. 1 is a sectional view of the novel switch of the present invention;

Fig. 2 is a sectional view of the novel switch of the present invention taken at right angles from the sectional view of Fig. 1;

Fig. 3 is an exploded pictorial view of the supporting structures of the pole-pieces and glass components of the novel switch of the present invention;

Fig. 4 is an exploded pictorial view of the armature drain, reservoir and glass tube of the novel switch of the present invention;

Fig. 5 is a partial sectional view of the armature taken along line 5 in Fig. 4;

Fig. 6 is a sectional view of the novel reservoir of the present invention taken along line 6—6 in Fig. 4; and

Fig. 7 is a sectional view of a modification of the novel reservoir of the present invention.

The magnetic structure in our Patent 2,609,464 which issued September 2, 1952 is incorporated herein by reference and is, therefore, not shown in Figs. 1 through 7. Referring to Figs. 1 through 6 the armature 10 is supported by the tubular stem 11 which is in turn secured in the base of the glass tube 12. The armature 10 has on its surface fine grooves or capillaries 13 longitudinally disposed as shown particularly in Fig. 5 and herein-after described. The armature 10 is tapered to provide a maximum magnetic cross-section for a given combination of compliance and natural frequency. The tapered shape of the armature 10 in this manner minimizes the mass and the magnetic leakage.

The tapered end of the armature 10 is positioned between and has approximately the same width as the pole-pieces 14 and 15 which are supported by a ceramic spacer 18 and the glass tube 12. The spacer 18 has a thermal expansion coefficient which is similar to that of the glass of tube 12 and is not wettable by the mercury. Without the spacer 18 the glass of tube 12 tends to form a channel between the pole-pieces 14 and 15 in which the mercury can collect and short-circuit the pole-pieces 14 and 15. The pole-pieces are, in the preferred embodiment, 0.060 inch diameter wires which are formed to provide as minimum a spacing therebetween as is consistent with successful operation. The pole-pieces 14 and 15 have welded thereto contacts 16 and 17, respectively, which are engageable by the armature 10 at a point which is close to a node for one of the major nodes of armature vibration. This engagement limits the amplitude of the mechanical bounce at a contact to an amount which can be bridged by the mercury and yet permit some dissipation of the impact transient.

The contacts 16 and 17 may be of any suitable material, but preferably of a platinum nickel alloy, having an 85 percent platinum to 15 percent nickel composition which is a composition harder than that of the armature 10. The contacts 16 and 17 are essentially small balls having a flat surface parallel to the plane of the armature 10. This flat surface is large enough to cover several of the grooves 13 on the armature 10. The contacts 16 and 17 can be formed by cutting the wire into fixed lengths, heat treating in hydrogen and dropping the cut lengths through an atomic hydrogen torch into water. In the preferred embodiment the cut lengths are approximately .008 inch in diameter and .021 inch long and are heat treated at 1000° C. in hydrogen for thirty minutes to de-gas them and reduce any oxide films. The cut lengths, or preforms, are fed down a trough or shaker, not shown, at an angle of 3 degrees from horizontal, dropped in single file through the frame of an atomic hydrogen welder or torch where they are fused into spheres by the action of surface tension of the melted alloy. The end of the trough is approximately 1 inch above and 5/8 inch ahead of the ends of the electrodes of the torch which is adjusted to draw approximately 45 amperes with a gas pressure of 7 to 8 pounds. This combination of parameters determines the portion of the flame that is used and the velocity of the preforms therethrough so as to obtain proper melting of the material. The water surface is almost in contact with the hydrogen flame, being located within 1 inch of the trough and close to the portion of the flame that melts the preforms. Locating the water proximate to the flame is necessary to prevent formation of oxide spots on the spheres due to their exposure to air while they are hot. The water is at least 4 and preferably 6 inches deep to insure the solidification of the spheres before they hit bottom. This method provides for contacts that are closely controlled as to diameter being $.0125 \pm .0005$ inch, and free from oxide films. This method provides for twenty contacts per second when the shaker is vibrated at 120 times per second. The contacts 16 and 17 are welded to the pole-pieces 14 and 15 and are flattened slightly after welding. When the mercury bridge breaks as the armature 10 moves away from the contact 16 or 17, the mercury which is left on the contact 16 or 17 forms a mercury cushion in the shape of a segment of a sphere on the contact 16 or 17. This mercury cushion thus makes contact with the mercury wet armature 10 on the next closure.

High gas pressure in tube 12 makes the contact gap capable of withstanding a high voltage gradient without breakdown. Because of this, and the high speed at which the gap increases when the mercury filament breaks, a high rate of voltage rise and a high peak voltage can develop across a contact which is opening, without producing an arc.

The area of contact on the armature 10 ordinarily

covers more than two of the capillary grooves 13. The construction of the switch or relay of the present invention may include an aging process which produces an indentation in the armature 10 approximately equal to the depths of the grooves 13. In the preferred embodiment of the present invention the contact spacing is such as to allow an armature travel of approximately .008 inch which results in a make-before-break operation. The armature 10 functions as the base of the mercury contact which meets with the contacts 16 and 17 described above, and also serves as the wick which feeds mercury to the contact area. These functions are accomplished by utilizing a surface composition on the armature 10 which insures good wetting by the mercury, and by a pattern of closely spaced grooves 13 described above which are rolled into the base.

Every time that the armature 10 separates from one of the contacts 16 or 17, a mercury bridge is formed therebetween which breaks in two places to release a drop of mercury. The grooves or capillaries 13 in the armature 10 must have a sufficiently low flow impedance to replenish this loss at the contact area at the maximum frequency of operation. When the switch is held in a horizontal position, as shown in Figs. 1 and 2, the drop of mercury which is formed when the armature 10 breaks or separates from one of the contacts 16 or 17 falls upon a drain 22 which is affixed to the inside of the glass tube 12 at the bottom thereof. The drain or drain element 22 is a strip of magnetic alloy which is wettable by mercury and which extends from the contact end of the tube 12 where it is held in the glass, to the other end of the glass tube 12 alongside a capillary reservoir 19, which is hereinafter described, where the drain 22 is held by the mercury. The cross-section of the drain 22 is sufficiently small so that the magnetic effects thereof can be neglected. Various modifications of the drain 22 may be provided without departing from the spirit of the present invention. For example, the drain 22 may be a non-magnetic alloy that is wettable by mercury or it may be provided with grooves or capillaries, not shown, similar to grooves 13 in the armature 10. The grooves on the drain 22 would be utilized when the reservoir 19, hereinafter described, is positioned above the contact area.

The reservoir 19 is formed from .002 inch sheet permalloy with a copper diffused surface and is shown particularly in Fig. 6. The reservoir 19 is formed to have a plurality of tubes 20 which are shaped to approximate cylindrical tubes by forming two series of scallops into a strip of material which, when rolled up and welded closed, forms two layers of tubes 20. The tubes 20 are connected to each other through cracks in the scalloping of the reservoir 19 so that mercury in the outer circumference of tubes 20 leaks through or can pass through to the inner circumference of tubes 20 to the armature 10. The capillary reservoir 19 is coupled mechanically to the armature 10 by means of the metal tube 11. The tube 11 is inserted through the central portion 27 of the capillary reservoir 19 and is attached to the armature 10.

In the vertical switch disclosed in our prior Patent 2,609,464 dated September 2, 1952, a negative head or pressure is maintained at the contacts, due to the fact that the contacts are always positioned above the mercury pool. The negative head at the contacts determines a number of operating characteristics of the relay such as the length of time for the mercury bridge to break, which is equivalent in the device of the present invention to the break or separating time of the armature 10 and one of the contacts 16 or 17. The negative head at the contacts 16 and 17 also affects the thickness of the mercury cushions and the positioning of the pole-pieces 14 and 15. In the switch of the present invention a negative head is provided at the contact area by means of the capillary reservoir 19 briefly described above. The capillary reservoir 19 is essentially a bundle of

tubes 20, the walls of which are wet by the mercury. The total amount of mercury enclosed in the glass tube 12 is such that the tubes 20 are only partially full of mercury. Since the tubes 20 are wet by the mercury, the contact angle between the mercury and the walls of the tube 20 is zero. The mercury menisci in the tubes 20 are therefore tangent to the inside walls. The surfaces of the mercury menisci in the tubes 20 have approximately a spherical contour with a radius equal to that of the tubes 20. This configuration of the surface fixes the pressure or the head inside the surface of the mercury referred to the outside pressure at a value

$$\Delta p = \frac{2T}{R}$$

where T is the surface tension of the mercury and R is the radius of curvature. The surface tension of the mercury is approximately 450 dynes per centimeter. The relative pressure Δp in terms of the equivalent negative head in height above a reservoir is equal to ρgh where ρ , the density, equals 13.6 grams per centimeter for mercury and g , the acceleration of gravity, is equal to 980 centimeters per second square. When the two values for Δp are equated the height h is equal to

$$\frac{.0676}{R}$$

Given the radius therefore of the mercury menisci in tubes 20, the equivalent negative head is determined. The radius of the tubes is approximately .033 centimeter which provides a negative head of 2.07 centimeters. When the switch is maintained in a horizontal position the negative head throughout the switch is substantially the same due to the relatively small variations in height of the mercury in the switch.

Every time that the armature 10 moves from one contact 16 or 17 to another, responsive to the operation thereof, a mercury bridge or filament is drawn out between the armature 10 and one of the contacts 16 or 17 which breaks in two places dropping a small ball of mercury to the drain 22. When the mercury reaches the drain 22 it establishes a positive head which, in conjunction with the negative head in reservoir 19, causes the mercury that falls upon the drain 22 to be drawn into the reservoir 19 which it contacts. The amount of mercury therefore in the reservoir 19 varies during the operating cycle of the switch of the present invention. Due to the fact that the negative head is solely a function of the radii of the tubes 20, the variation in the amount of mercury in the reservoir 19 does not change the negative head.

The repeated operation of the switch of the present invention provides for a circulation of the mercury, starting with the displaced drops at the contacts 16 and 17 which impinge upon the drain 22 and flow to the reservoir 19, which replenishes the mercury at the tip of the armature 10. If a greater negative head is required than that provided by the reservoir 19, tilting the switch so that the contact area is higher than the reservoir 19 will increase the negative head at the contact area. If a smaller negative head is required tilting the switch so that the contact area is lower than the reservoir 19 will decrease the negative head at the contact area. The negative head at the contacts is therefore readily changed or adjusted by tilting the switch. In the vertical switches existing in the prior art the negative head at the contacts can be materially increased by a factor of two or more by including therein a capillary reservoir of the present invention.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of this invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention as, for example, the shape of the reservoir may be varied as

shown in Fig. 7 wherein a reservoir 25 has arcuately shaped tubes 26.

The tube 20 in reservoir 19 and tube 26 in reservoir 25 having constant bores, represent one simple way of establishing a negative head which is independent of the amount of mercury in the reservoir 20 or 25, as long as they are not full. Other configurations are equally effective, provided that the principal radii of the mercury fillets which form in them are in accord with the general formula

$$h = \frac{T}{\rho g} \left(\frac{1}{r_1} + \frac{1}{r_2} \right)$$

where h is the equivalent negative head T is the surface tension, ρ is the density, g is the acceleration of gravity and r_1 and r_2 are the principal radii of curvature of the surface (taken in planes cutting the surface at right angles). For mercury

$$h = .0338 \left(\frac{1}{r_1} + \frac{1}{r_2} \right)$$

and when $r_1 = r_2$, as in the case of a spherically shaped surface as described above, $h = .0676R$. A reservoir constructed to provide fillets or surfaces of mercury in accordance with the general formula above would provide a constant negative head. For example, a reservoir constructed of parallel plates which is partially full of mercury has mercury menisci of substantially cylindrical shape with one principal radius of curvature equal to one-half the distance between two adjacent plates, the other principal radius of curvature being relatively very large. The equivalent negative head for such a construction would be approximately .0676 divided by the distance between two adjacent plates. The plates may be circular in shape, or discs, to provide arcuately shaped cylindrical menisci, and still other arrangements may be devised by those skilled in the art in accordance with the principles described above without departing from the spirit and scope of the invention.

What is claimed is:

1. A mercury contact switch comprising mercury wettable contacts, a capillary reservoir having constant bore capillaries, an armature mating with said contacts and providing a mercury path from said reservoir to said contacts, and a drain element for returning displaced mercury from said contacts to said reservoir upon the operation of said armature.
2. A contact device having mercury wetted contacts, a mercury wettable reservoir, a pool of mercury trapped in said reservoir, a wick member for supplying mercury to said contacts from said pool, and a mercury wettable drain element for returning the mercury from said contacts to said pool.
3. A contact device in accordance with claim 2 wherein said reservoir comprises a plurality of constant bore tubes effecting a constant negative head at said contacts.
4. A contact device in accordance with claim 3 wherein said wick member consists of a tapered armature having a plurality of grooves longitudinally disposed between said reservoir and said contacts.
5. A relay comprising a hermetically sealed tube, an armature arranged longitudinally within said tube, pole-pieces extending through said sealed tube, contact points secured upon said pole-pieces, said armature extending between said contact points, at least one column of mercury in said tube, means for maintaining said column of mercury in capillary suspension, said armature providing a mercury path between said column and said contacts.
6. A relay in accordance with claim 5 wherein said column of mercury has a constant cross-section.
7. A relay in accordance with claim 6 comprising in addition a strip of wettable material for returning the mercury from said contacts to said column.
8. A horizontal mercury switch comprising contacts,

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mercury wettable supply means for providing a negative head of mercury at said contacts, and mercury wettable means for returning the mercury from said contacts to said first means to effect a circulation of the mercury when the contacts are operated.

9. A mercury relay comprising contacts, a reservoir, a wick connecting said contacts with said reservoir, and a pool of mercury partially filling said reservoir, said reservoir having members forming similar mercury menisci.

10. A mercury relay in accordance claim 9 wherein said members are tubes having constant cross-sections.

11. A mercury relay in accordance with claim 9 wherein said members are parallel plates forming cylindrically shaped mercury menisci.

12. A mercury relay in accordance with claim 10 comprising in addition a wettable drain element for returning displaced mercury from said contacts to said reservoir.

13. A mercury switch having a contact area, a wettable armature, a mercury pool, a reservoir containing said mercury pool in contact with said armature and forming a plurality of curved surfaces in said pool, means for operating said switch and displacing some mercury from said contact area, and mercury wettable means for returning the displaced mercury from said contact area to said pool.

14. A mercury switch in accordance with claim 13 wherein said contact area, said armature and said pool are substantially horizontally disposed.

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15. A mercury switch in accordance with claim 13 wherein said contact area is lower than said pool.

16. A mercury switch in accordance with claim 14 wherein said reservoir is wettable and has a plurality of passageways of constant cross-section.

17. A mercury switch in accordance with claim 14 wherein said reservoir is wettable and has a plurality of passageways having the same cross-section to form equally shaped curved surfaces in said pool each of said passageways having a constant cross-section from one end to the other.

18. A mercury switch in accordance with claim 17 wherein said means for returning the displaced mercury is a wettable drain strip.

19. A mercury switch in accordance with claim 18 wherein said wettable drain strip has a plurality of surface grooves.

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