

Sept. 18, 1962

W. D. O'BRIEN ET AL
LIQUID-CONTACT SWITCH

3,054,873

Filed Nov. 27, 1959

2 Sheets-Sheet 1

FIG. 1

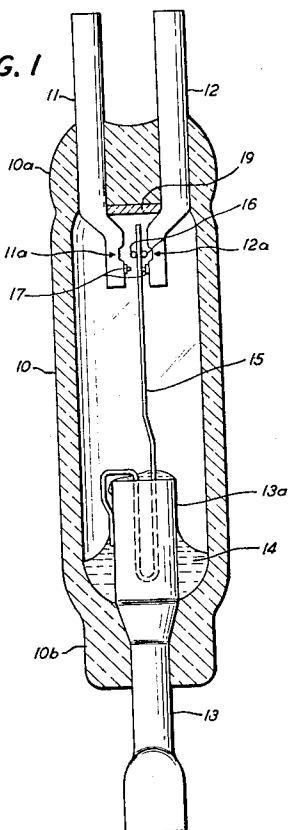


FIG. 2

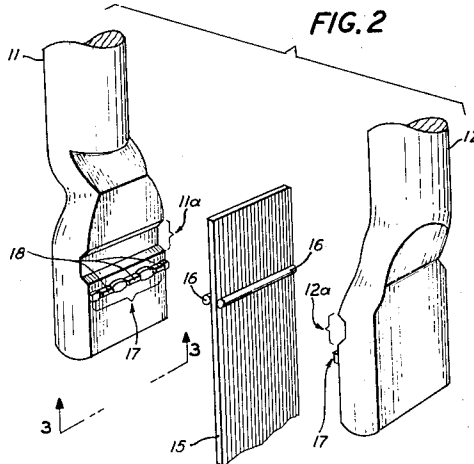


FIG. 3

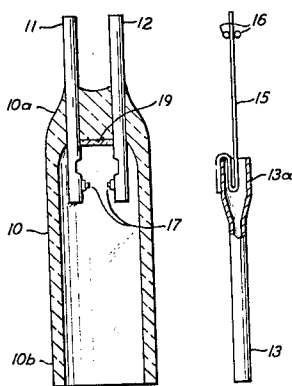
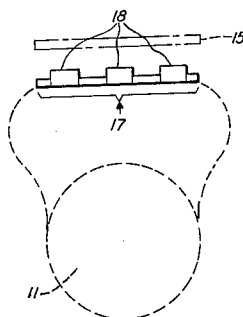


FIG. 4

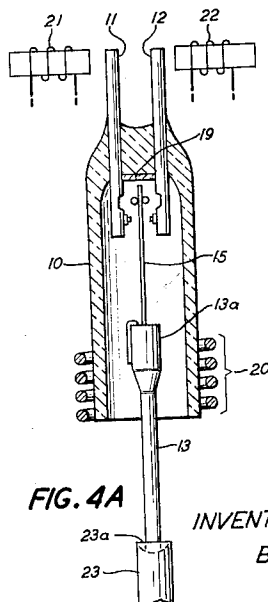


FIG. 4A

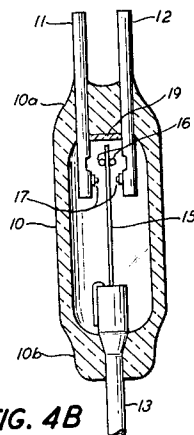


FIG. 4B

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FIG. 5B

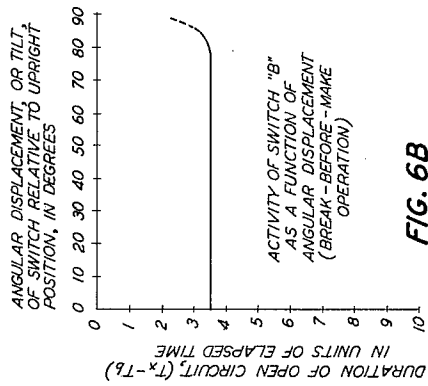
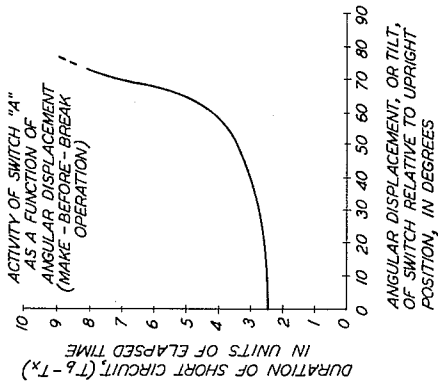


FIG. 6B

FIG. 5A

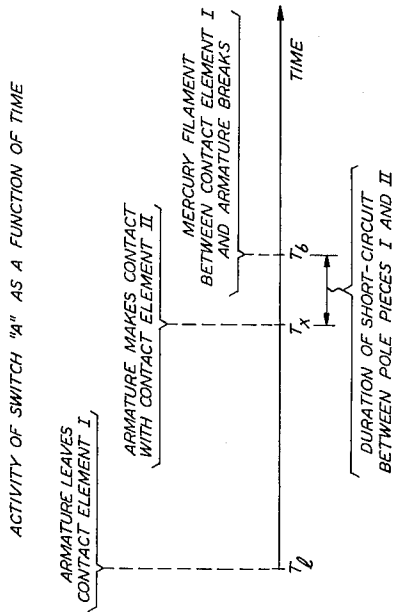


FIG. 6A

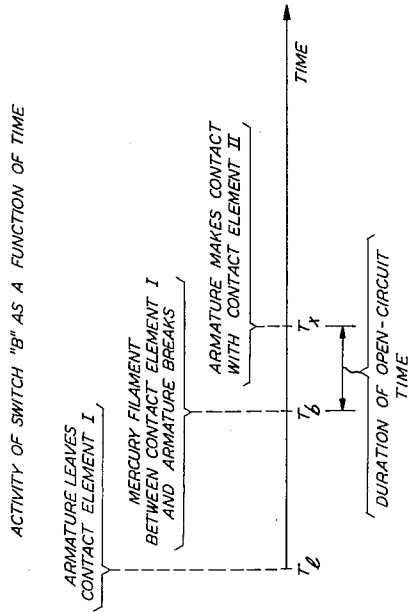


FIG. 5

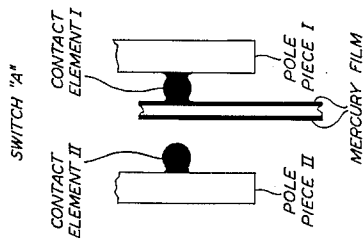
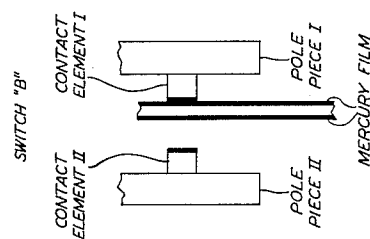


FIG. 6



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LIQUID-CONTACT SWITCH

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Filed Nov. 27, 1959, Ser. No. 855,722

8 Claims. (Cl. 200-112)

This invention relates, in general, to switching devices using an electrically conductive liquid as a contact-making medium; and, in particular, to switching devices of the type wherein a film of liquid, such as mercury or the like, adheres to a solid contact member and serves as the contact surface thereon. For convenience, switching devices of this type are hereinafter referred to, generically, as liquid-contact switches; and, when it is particularly appropriate, such switching devices are referred to as mercury-contact switches.

In typical embodiments of the liquid-contact switch, small quantities of an electrically conductive liquid migrate from a large mass of such liquid along the surfaces of a movable, solid contact member due to the adhesive force between the liquid and the solid contact member. In order to promote the liquid's migration, capillary paths are provided on the surface of the movable member. As a consequence, the movable member becomes coated with a film of liquid. In response to an operating signal, the liquid-coated contact member is moved, selectively, into engagement with a contact element on a fixed contact member, among a plurality of fixed contact members, thereby completing an electrical circuit. A recent example of such a switching device is the mercury contact switch described in the specification of, and illustrated in the drawing accompanying, the United States Patent 2,868,926, granted to C. E. Pollard, Jr. on January 13, 1959; an earlier example is the mercury-contact switch described in the specification of, and illustrated in the drawing accompanying, the United States Patent 2,609,464 granted to J. T. L. Brown and C. E. Pollard, Jr. on September 2, 1952.

Although the liquid-contact switch is ideally suited for performing a variety of switching operations, the functioning of such a switch is seriously impaired when, during the operation of the switch: too much liquid accumulates on the fixed contact members' contact elements; or, too much liquid accumulates in the regions between adjacently situated fixed contact members. This accumulation of liquid occurs in, among others, the following ways:

(1) As the movable contact member makes contact with a fixed contact member's contact element some of the liquid at the interface between the movable member and the contact element is squirted from the interface at a relatively high velocity. Often, large quantities of this high velocity liquid accumulate between adjacently situated fixed contact members. Often, too, large quantities of this high velocity liquid accumulate on the contact elements.

(2) The rapid movement of the liquid-coated contact member and its impact against the contact elements causes small globules of liquid to "fly" with a relatively high velocity from the liquid-coated member. Often, many of these high velocity globules accumulate between adjacently situated fixed contact members. Often, too, many of these globules accumulate on the contact elements.

(3) As the movable contact member breaks contact with a fixed contact member's contact element a filament of liquid maintains a bridge between the movable member and the contact element for a short period of time. Eventually, the liquid filament is severed and a small liquid globule having a relatively low velocity is thereby

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ejected and randomly directed. This activity is illustrated and described at pages 1397, 8, 9 of volume 32, "The Bell System Technical Journal" (November 1953). Often, such randomly directed globules accumulate on the contact elements; sometimes they accumulate between adjacently situated fixed contact members.

(4) Affixed to the fixed contact members are contact elements which have relatively large "liquid-wettable" areas thereon. As a consequence, large quantities of liquid adhere to the contact elements.

The accumulation of liquid, occurring in the ways hereinbefore described, causes, among others, the following functional impairments:

(1) Malfunctioning of the switch; e.g., in the mercury-contact switch, mercury globules collect between adjacently situated fixed contact members in the ways hereinbefore described. Eventually, a short circuit is established between the fixed members. Often, a short circuit is momentarily established between a fixed member and the movable member. For another example, in a single-pole, double-throw type of mercury-contact switch, the movable contact member is often required to break a connection with a first fixed contact member before making a connection with a second fixed contact member. However, large quantities of mercury adhering to the fixed contact members' contact elements will prevent the switch from performing such a function. Instead of the desired function, a "make-before-break" operation will occur because the accumulated mercury on the fixed contact members' contact elements tends to maintain a mercury bridge, or filament, between the movable contact member and the first fixed contact member. Consequently, the movable contact member will engage the second contact member before the connection between the movable contact member and the first contact member is broken. The well-known bridging characteristic of mercury is discussed in the specification of, and illustrated in the drawings accompanying, the United States Patent 2,406,036 granted to C. E. Pollard, Jr. on August 20, 1946.

(2) The switch's response to an operating signal is delayed; often for an intolerably long period of time. For example, in applications where a mercury-contact switch is required to break a circuit connection rapidly, such an objective will be frustrated because a large accumulation of mercury on a fixed contact member's contact element tends to maintain a mercury bridge, or filament, between the contact element and the movable contact member for a relatively long period of time after the initiation of a circuit-breaking signal.

(3) The range over which the liquid-contact switch can reliably perform a given switching function is often temporarily attenuated. For example, the mercury-contact switch can function as a vibrator; i.e., it can make and break an electrical connection many times a second. However, the accumulation of mercury on the fixed contact members will, according to the quantity of mercury accumulated, diminish the maximum frequency at which the switch can reliably perform as a vibrator because a large quantity of mercury accumulated on the fixed contact members tends to maintain a mercury bridge in the manner hereinbefore discussed. As a consequence, the switch will reliably perform as a vibrator in the relatively lower range of frequencies only.

(4) The accumulation of liquid on the fixed contact members' contact elements prevents the switch from functioning reliably when it is not in an upright, or nearly upright, position. For example, if a mercury-contact switch of the general type disclosed in the patents hereinbefore noted is tilted from its upright position, a greater amount of mercury will migrate upwardly along the movable contact member. Consequently, a correspondingly greater amount of mercury will adhere to the relatively large

"mercury-wettable" area on the fixed contact members' contact element which has been moved closer to the mercury mass; i.e., its head with respect to the mercury mass has been reduced. As the switch is tilted through progressively greater angles from its upright position, its response becomes progressively poorer. Eventually, at a critical angle, a large quantity of mercury, accumulated on the contact element, causes a short-circuit condition. A more detailed discussion of this type of functional impairment is included in the following publications: (1) "Mercury Contact Relays" by J. T. L. Brown and C. E. Pollard in volume 66, "Electrical Engineering," November, 1947, at page 1107; (2) "Balanced Polar Mercury Contact Relay" by J. T. L. Brown and C. E. Pollard in volume 32, "Bell System Technical Journal" (1953), beginning at page 1393; and (3) the specification of the United States Patent 2,769,875 granted to J. T. L. Brown and C. E. Pollard, Jr. on November 6, 1956.

Therefore, the objects of this invention include: The improvement, structurally and functionally, of liquid-contact switches; the achievement of a liquid-contact switch which is free from the types of functional impairments hereinbefore noted; the achievement of a liquid-contact switch wherein the accumulation of liquid between the fixed contact members is virtually eliminated, the achievement of a liquid-contact switch wherein the accumulation of liquid on the contact elements is kept to a minimum; the achievement of a liquid-contact switch which will operate reliably though tilted appreciably from its upright position; and, the attainment of these objects with simple, reliable and economical means.

The invention, illustratively embodied in the mercury-contact switch hereinafter described, achieves the aforementioned objects, as well as others appearing hereinafter, by the provision of a liquid-contact switch comprising: a fixed contact member having a relatively small, liquid-wettable contact area thereon; a liquid-coated contact member adaptable of being moved into engagement with the contact area on the fixed contact member; and, intercepting means for preventing mobile portions of the liquid from short-circuiting the switch.

Accordingly, a liquid-contact switch including the following features is achieved:

(1) Fastened to a fixed contact member is a contact element having a number of spaced-apart contact surfaces thereon. Except for the relatively small contact surfaces on each contact element, liquid will not adhere very well to the surfaces of the fixed contact member; nor to the contact elements. Advantageously, very small quantities of liquid adhere to each of the contact surfaces.

(2) Fastened to the liquid-coated movable contact member is a baffle member which intercepts squirted liquid as well as liquid globules. Advantageously, liquid will not accumulate in the region between the fixed contact members to cause the functional impairments hereinbefore noted.

(3) The fixed contact member has a trough, or recessed portion, incorporated therein; so situated that it faces the baffle member. The trough's function, described in detail hereinafter, is to trap or deflect the squirted liquid and the liquid globules. Advantageously, liquid will not accumulate in the region between the fixed contact members, causing the functional impairments hereinbefore noted.

Other objects and features, as well as a fuller understanding of the invention, will appear by referring to the following description and claims taken in conjunction with the accompanying drawings in which:

FIG. 1 is a view of a longitudinal cross-section of a mercury-contact switch embodying the invention;

FIG. 2 is a magnified view of part of the movable contact member, or armature, and the fixed contact members, or pole pieces;

FIG. 3 is an end view of one of the pole pieces shown

in FIG. 2, taken along the lines 3—3, showing the arrangement of a contact element on the pole piece;

FIGS. 4, 4A and 4B are views, in longitudinal cross-section, showing the mercury switch of FIG. 1 at successive stages of its assembly;

FIG. 5 is a partial view of a mercury-contact switch, designated as switch A, having the kind of contact elements that are typical of the prior art;

FIG. 5A is a graphical representation showing the activity of switch A, shown in FIG. 5, as a function of time;

FIG. 5B is a graphical representation showing the activity of switch A, shown in FIG. 5, as a function of the angular displacement of the switch;

FIG. 6 is a partial view of a mercury-contact switch, designated as switch B, having the contact elements of this invention;

FIG. 6A is a graphical representation showing the activity of switch B, shown in FIG. 6, as a function of time; and

FIG. 6B is a graphical representation showing the activity of switch B, shown in FIG. 6, as a function of the angular displacement of the switch.

Referring now to the drawings and especially to FIG. 1, there illustrated is a mercury-contact switch comprising: an envelope 10; a mass of mercury 14, resting within the envelope; a pair of pole pieces, 11 and 12, sealed within and protruding through the envelope; a tubular mounting stem 13, sealed within and protruding through the envelope; and, a reed-like armature 15, affixed to the mounting stem. The armature 15 has, at one end thereof, a looped portion which is fitted into, and affixed to, a flared portion 13a of the stem 13. The advantages accruing from the use of a flared mounting stem and an armature having a looped end portion are discussed in the Patent 2,868,926 hereinbefore noted.

The pole pieces 11 and 12 are aligned in parallel relationship and a spacer 19 of ceramic material is positioned between them. As is illustrated at FIG. 1, the pole pieces are sealed through one end 10a of the envelope; the spacer 19 being situated therebetween and abutting the inside surface of the envelope's end 10a. The envelope 10 is formed from a tubulation of non-magnetizable and electrically nonconductive material such as glass or the like. Without the ceramic spacer 19, the inside surface of the glass envelope's end 10a would tend, as heat is applied thereto for the purpose of sealing the envelope, to form a channel or groove in which mercury could collect and establish a short circuit between the pole pieces. Advantageously, the ceramic spacer 19 has a coefficient of thermal expansion which closely matches that of the glass envelope. The pole pieces are formed from a magnetizable material having surfaces which are not wetted by mercury, i.e., mercury will not adhere very well thereto. For example, an alloy comprising essentially 52% nickel and 48% iron has suitable magnetic characteristics; and when the alloy's surfaces are finished with a plating of chromium-oxide, mercury will not adhere very well thereon.

In addition, each pole piece has a trough, or recessed portion, formed therein; the pole piece 11 having a trough designated, generally, by the reference character 11a; and, the pole piece 12 having a trough designated, generally, by the reference character 12a. These troughs are used for trapping and deflecting squirted mercury and mercury globules. These mercury-trapping and mercury-deflecting functions are discussed in greater detail hereinafter.

Referring now to the FIGS. 2 and 3 in the drawings, whereat the pole pieces are conveniently illustrated in a magnified view, there is affixed to each pole piece a contact element designated, generally, by the reference character 17. Each contact element 17 presents a plurality of small, flat contact surfaces 18 to the armature reed 15. Although three contact surfaces 18 are shown at FIGS. 2 and 3 of the drawings, it is to be understood that more

than three contact surfaces, or less than three contact surfaces, may be employed. Each contact element 17 is formed from a material having, among others, the following preferred properties: sufficient hardness so that it will wear well; relatively low electrical resistance; and, except for the flat contact surfaces 18 thereon, its other surfaces must be such that mercury will not adhere very well thereto. For example, each contact element 17 may be formed into the shape shown in the drawings from a small wire of a platinum-nickel alloy. An alloy comprising essentially 85% platinum and 15% nickel will have the desirable electrical resistance and hardness properties; such an alloy being harder than the preferred material hereinafter suggested for the fabrication of the armature 15. In order to achieve surfaces which are not wetted by mercury, the platinum-nickel wire is plated with a material which is not wetted by mercury. For example, a plating of chromium oxide, or the like, is suitable. Subsequently, the chromium-oxide plated surfaces 18, only, are subjected to a surface grinding operation. This grinding operation achieves two beneficial results, viz: (1) the chromium-oxide plating on the contact surfaces 18 is removed so that the platinum-nickel alloy is exposed thereby providing a surface to which mercury will adhere well; and (2) the contact surfaces 18 acquire a smooth flat finish thereby enabling the armature reed 15 to effect a good surface-to-surface contact therewith. Advantageously, the contact elements 17 having the smooth, flat, mercury-wettable surfaces 18 will retain but a minimum amount of mercury. The retained mercury, being confined to the surfaces 18, does not tend to form fillets with either the contact elements 17 or the armature 15. The tendency of mercury to form such fillets, allowing unduly large quantities of mercury to accumulate on the contact elements, is illustrated in the Patent 2,406,036, hereinbefore noted.

The flared tubular stem 13 having the armature reed 15 affixed thereon, as shown, is sealed to and protrudes through the end 10b of the envelope. One method of fabricating the armature and stem assembly is discussed in the Patent 2,868,926 hereinbefore noted. The armature reed 15 is formed from a magnetizable material, and its surfaces are such that they are wetted by mercury. For example, an alloy comprising essentially 78% nickel and 22% iron has suitable magnetic characteristics. The nickel-iron reed's surfaces have a number of capillary grooves arranged longitudinally therein as shown at FIG. 2. Subsequently, the reed is plated with a material to which mercury will adhere well, such as nickel, or the like; the result being a nickel-plated reed including capillary grooves in its surfaces to aid the migration of mercury along the reed's surfaces. Similarly, the stem 13 is formed from a tubulation of magnetizable material; e.g., a nickel-iron alloy consisting of 52% nickel and 48% iron is suitable.

Affixed to the end of the armature reed 15 is a pair of baffles 16; one on each face of the reed 15 as shown at FIGS. 1 and 2 of the drawings. For example a solid nickel wire, or a nickel-plated nickel-iron alloy is a suitable material. As is shown at FIG. 1, the baffles are situated on the armature 15 in a position adjacent to the troughs 11a and 12a. When the armature 15 moves into contact with the contact surfaces 18 on one of the contact elements 17, the baffle is "nested" within the trough adjacent to the contact element. The interaction of the baffles and the troughs is purposeful to trap and deflect squirted mercury and mercury globules. This is discussed in greater detail hereinafter.

Referring now to the FIGS. 4, 4A, and 4B, showing the assembly of the mercury-contact switch of FIG. 1 at certain stages of its assembly, an additional advantage of using the contact elements 17 having plural contact surfaces 18 is illustrated. Briefly, at FIG. 4, two sub-assemblies appear, viz.: one is the subassembly including the glass envelope 10 and the pole pieces 11 and 12

sealed through the envelope's end 10a; the second is the stem-and-armature subassembly, 13-and-15.

A major problem encountered in assembling these sub-assemblies is the difficulty in achieving accurate alignment, within the envelope, between the armature and the contact elements. Of course, in the so-called miniature switches it is very difficult to achieve an accurate alignment. At FIG. 4A, there is shown, in simplified form, apparatus for aligning the armature with the contact elements, rapidly and accurately. Stem 13 rests on a bearing 23 having a cupped end portion 23a; the flared portion 13a of the stem and the armature 15 being situated within the envelope 10. Two electromagnets, 21 and 22, are positioned outside the envelope next to the pole pieces, 11 and 12, as shown. The electromagnets are alternately energized; and, as a consequence, the armature 15, as well as the stem 13, vibrates back and forth from the contact element 17 on one pole piece to the contact element 17 on the other pole piece. The result of the electromagnetically induced vibration of the stem-and-armature subassembly is that the contacting surfaces of the armature 15 are aligned in face-to-face relation with the flat contact surfaces 18. The armature 15 is virtually self-aligning when it is electromagnetically vibrated in accordance with the technique hereinbefore described; i.e., the armature 15 will eventually assume a position that is equidistant from both contact surfaces 18 and the armature's contacting surfaces will be in parallel alignment with the flat contact surfaces 18. Accordingly, the armature 15, during its operation in the finished switch of FIG. 1, will make contact with all of the contact surfaces 18, simultaneously, on one of the contact elements 17. The employment of the aligning apparatus in the manner described herein is especially advantageous in that the armature 15, however much it may be out of alignment initially, will become properly aligned as aforesaid due to the forces exerted by the alternately present magnetic fields on the armature 15. While the armature and stem assembly is vibrating the heating coil 20 is energized, and, as a consequence, the glass will slowly become fluid and flow about the stem 13. Subsequently, the heating coil 20 is de-energized and the glass is allowed to cool. During the cooling period, the stem-and-armature subassembly tends to vibrate. Eventually, the glass solidifies and anchors the stem whereby the armature's alignment becomes fixed; the armature having assumed a normal position which is substantially equidistant from each of the contact elements. The result is the structure shown at FIG. 4B. The required mass of mercury is then inserted into the envelope through the aperture in the tubular stem 13. In addition, the envelope may be gas-filled; for example, dry hydrogen under pressure provides a suitable atmosphere.

Although the mode of operation of the mercury-contact switch is well known to those skilled in this art, it is described, briefly, in the following paragraphs for the purpose of illustrating the advantages accruing from the employment of the baffles 16, the troughs 11a and 12a, and the contact element 17.

The mercury-contact switch is commonly employed in combination with a control coil (not shown in FIG. 1), disposed about the envelope 10, and a pair of permanent magnets (not shown in FIG. 1) coupled with the pole pieces, 11 and 12, respectively. This structural combination is a typical embodiment of the so-called polarized relay; the permanent magnets creating mutually opposing magnetic poles in the pole pieces 11 and 12, respectively. (See, for example, the Patent 2,609,464 hereinbefore noted.) As is illustrated at FIG. 1, the switch is in its normal, or unoperated status; i.e., the coil (not shown) is not energized and the armature 15 is held in contact with the contact element on pole piece 12 because the magnetic pole created in pole piece 12 is strong enough to attract the armature 15 and magnetically stronger than the magnetic pole created in pole piece 11. In short, such a relay is

a magnetically biased, polarized relay. When the coil is energized so that sufficient current passing therethrough creates a condition such that the armature 15 and the pole piece 12 present like magnetic poles to each other, the armature 15 will move into contact with the contact element 17 on pole piece 11; the pole piece 11 and the armature 15 presenting unlike magnetic poles to each other. When the coil is de-energized armature 15 returns to its normal position; i.e., in contact with the contact element 17 on pole piece 12.

Of course, those persons skilled in this art will understand that the mercury-contact switch can be employed in many devices and in many ways. For example, it may be employed in a magnetically latching polar relay; i.e., the permanent magnets are of substantially equal magnetic strength and in addition sufficiently strong to latch, or hold, the armature to whichever pole piece it is at when the coil is de-energized. Advantageously, current pulses of short duration, as well as of proper magnetic polarity, will allow the armature 15 to transfer from one pole piece to another and become magnetically latched to the latter pole piece.

The impact of the mercury-coated armature 15 against the contact surfaces 18 on one of the contact elements 17 causes: mercury to be squirted from the interface between the armature and the contact surfaces 18; and, mercury globules to be ejected from the armature's surfaces. A large portion of the squirted mercury is directed toward the region between the pole pieces 11 and 12 at the end 10a of the envelope. Some of the squirted mercury splatters onto the pole piece and its contact element. The ejected mercury globules are randomly directed: Often, many of these globules are directed toward the region between the pole pieces 11 and 12 at the end 10a of the envelope; often, some of the globules splatter onto the pole piece and its contact element.

Some of the squirted mercury and some of those mercury globules which are directed toward the region between the pole pieces are intercepted by the baffle 16; some of the squirted mercury and some of the mercury globules are trapped in the trough, 11a or 12a; and some of the squirted mercury and some of the mercury globules are deflected back onto the armature as the baffle nests within the trough when the armature 15 makes contact with the contact surfaces 18. As a consequence, mercury will not tend to collect, among other places, between the pole pieces to cause a short-circuit condition.

The squirted mercury and the mercury globules which splatter onto the pole piece and its contact element 17 will tend to run off and drop into the mercury mass 14 because of the relatively large chromium-oxide coated surfaces on the pole piece and its contact element 17. The forces of cohesion on the mercury are relatively more dominant than the forces of adhesion between the mercury and the chromium-oxide coated surfaces. Hence, the squirted mercury and the mercury globules will tend to run off such surfaces. Since the relatively small mercury-wettable contact surfaces 18 are able to retain but a small amount of mercury and since the chromium-oxide coated surfaces promote the mercury's run-off, mercury will not tend to collect in large masses on the contact elements 17 to cause the functional impairments hereinbefore discussed.

In summary, therefore, the baffles, the pole pieces having troughs incorporated therein, and the contact elements having a plurality of small mercury-wettable contact surfaces provide a mercury-contact switch that is free of the functional impairments hereinbefore illustratively described. For example, the intercepting, the deflecting and the trapping of the squirted mercury and the mercury globules by the baffles and the troughs prevent a short circuit condition. The run-off of the mercury and the controlling of the minimum quantity of mercury on the contact surfaces: permits a rapid cir-

cuit-breaking action, eliminating the make-before-break malfunction; eliminates the intolerably long delay in response to an operating signal; eliminates attenuation at the maximum frequencies at which the switch can reliably perform; and, as is more fully described in the following paragraphs, the switch can operate reliably even though it is tilted appreciably from its upright or normal position.

Referring now to the FIGS. 5, 5A, 5B, 6, 6A and 6B of the accompanying drawings, the activity of two-mercury contact switches are compared, graphically, as: (1) a function of angular displacement, or tilt, from their upright, or normal, attitude of zero degrees; and (2) a function of time.

Switch A has, as is illustrated at FIG. 5, contact elements of the type employed in mercury-contact switches of the prior art; i.e., each contact element is generally ball-shaped, and its entire surface area is mercury-wettable. Thus, a relatively great amount of mercury adheres to each ball-shaped contact element; the mercury forming fillets with the contact elements, as shown. Switch B has, as is illustrated at FIG. 6, contact elements of the type embodying the instant invention; i.e., each contact element has a relatively small, flat contact surface and the contact surface, only, is mercury-wettable. Thus, a relatively small amount of mercury adheres to the contact elements of the instant invention; the mercury does not form fillets with the contact elements.

Except for the differences relating to the configuration of the contact elements and the extent of the mercury-wettable surfaces thereon, switch A and switch B are substantially alike; dimensionally, as well as in other respects. But, the operation of switch B, as well as its functioning in response to angular displacement from its upright position, is markedly different as compared to switch A. Switch A, because of the relatively large quantity of mercury adhering to its contact elements, performs a "make-before-break" operation. That is to say, when the armature leaves contact element I at the instant of time T_1 and travels from contact element I over to contact element II, a filament of mercury is drawn out between the moving armature and the contact element I. This filament sustains itself until some instant of time, T_b , after the armature makes contact with contact element II at instant of time T_x . As is shown at FIG. 5A in the graph labeled "Activity of Switch A as a Function of Time," the mercury filament sustains for a duration of time represented as $(T_b - T_1)$, mathematically; and, the contact elements I and II are short-circuited for a duration of time represented as $(T_b - T_x)$, mathematically. As is shown at FIG. 5B in the graph labeled "Activity of Switch A as a Function of Angular Displacement," the effect of tilting switch A, progressively, from its upright, or normal, attitude is to increase the duration of short-circuit time $(T_b - T_x)$; the duration of short-circuit time becoming much greater as the attitude of the switch approaches a ninety degree tilt from its normal attitude.

Switch B, because of the relatively small quantity of mercury adhering to its contact elements, performs a "break-before-make" operation. That is to say, when the armature leaves contact element I at the instant of time T_1 and travels toward contact element II, a filament of mercury is drawn out between the moving armature and the contact element II. Unlike the activity of switch A, however, this mercury filament does not sustain itself until after the armature makes contact with contact element II. It ruptures at the instant of time T_b . Thereafter, at the instant of time T_x the armature makes contact with contact element II. As is shown at FIG. 6A in the graph labeled "Activity of Switch B as a Function of Time," the mercury filament sustains for a duration of time represented as $(T_b - T_1)$, mathematically; and,

the switch is open-circuited for a duration of time represented as $(T_x - T_b)$, mathematically. As is shown at FIG. 6B in the graph labeled "Activity of Switch B as a Function of Angular Displacement," the tilting of switch B, progressively, from its upright, or normal, attitude has virtually no effect on the duration of the open-circuit time $(T_x - T_b)$. The duration of open-circuit time is undisturbed; i.e., it is stable throughout most of the range from zero degrees to ninety degrees.

Accordingly, a comparison of the graphs of the FIGS. 5A and 5B with the graphs of the FIGS. 6A and 6B, respectively, indicates, inter alia, the following significant differences in operation:

(1) The elapsed time $(T_b - T_1)$ during which a mercury filament is sustained is shorter in switch B than in switch A.

(2) The elapsed time $(T_b - T_1)$ during which the mercury filament is sustained in switch B is relatively constant throughout nearly the entire angular displacement range, 0° to 90° , whereas the elapsed time $(T_b - T_1)$ for switch A increases rapidly throughout the range and a short-circuit condition eventually occurs at an angle appreciably smaller than in switch B.

Although the invention has been described and illustrated by way of a specific embodiment thereof, it should be understood that many changes in details of construction and in the combination and arrangements of parts may be made without departing from the spirit and scope of the invention as it is hereinafter claimed.

What is claimed is:

1. A liquid-contact switch comprising: an envelope; a fixed contact member including a part thereof sealed within the envelope, said part including a relatively small contact surface thereon and a trough portion therein, the contact surface, only, being liquid-wettable; a liquid-coated movable contact member arranged within the envelope and having a contact-making portion thereon; a baffle member affixed adjacent to the movable member's contact-making portion; and, means for moving the movable member whereby the contact-making portion contacts the fixed member's contact surface and the baffle member is positioned at least partly within the trough portion.

2. A liquid-contact switch comprising: a pole piece having surfaces which are not liquid-wettable and a recessed portion included thereon; a contact element including a contact surface thereon, the contact surface, only, being liquid-wettable, the contact element being affixed to the pole piece at a position adjacent to the recessed portion thereon; a liquid-coated movable member including a contact-making portion thereon, the movable member's contact-making portion being normally spaced apart from the contact element; a baffle member affixed to the movable member at a position adjacent the contact-making portion thereof, the baffle member facing the recessed portion in the pole piece; and, actuating means operable for moving the movable member toward the contact element so that the movable member's contact-making portion contacts the contact element's contact surface and positions the baffle member at least partly within the recessed portion of the pole piece.

3. A liquid-contact switch comprising: a plurality of fixed contact members, each including a relatively small contact surface thereon and a trough portion therein, the contact surface, only, being liquid-wettable; a liquid-coated movable contact member; a plurality of baffle members, each baffle member being affixed to the movable contact member; and means for moving the movable

member into contact with a selected fixed contact member's contact surface thereby positioning one of the baffle members at least partly within the trough portion in the selected fixed contact member.

4. A liquid-contact switch comprising: a fixed contact member including a relatively small contact surface thereon and a trough portion therein, the contact surface, only, being liquid-wettable; a liquid-coated movable contact member; a baffle member affixed to the movable member; and, means for moving the movable member into contact with the fixed member's contact surface and positioning the baffle member at least partly within the trough portion.

5. A liquid-contact switch comprising: an envelope of non-magnetizable, electrically nonconductive material; a quantity of an electrically conductive liquid within the envelope; a deflectible armature, including liquid-wettable surfaces, sealed through one end of the envelope and extending therewithin; a pair of contact elements arranged within the envelope so that each contact element is spaced apart from the other contact element and from the armature, each contact element having a plurality of spaced-apart liquid-wettable contact surfaces thereon, the contact elements' other surfaces being essentially unwettable; a pair of pole pieces arranged in spaced-apart relation and sealed through the other end of the envelope, each pole piece having one of the contact elements affixed thereto, each pole piece including a trough arranged transversely therein and situated adjacent the contact element thereon, the surfaces of each pole piece being essentially unwettable; a pair of barrier members affixed to the armature and so situated thereon that each barrier member is in juxtaposed relation with one of the troughs; and, means for deflecting the armature toward either pole piece whereby the armature makes contact with the contact surfaces of one of the contact elements and a barrier member is nested in the trough adjacent the contact element so contacted.

6. A liquid-contact switch comprising: a fixed contact member including a relatively small liquid-wettable contact surface thereon; a liquid-coated contact member adaptable for making contact with the fixed member's contact surface; and, baffle means on the liquid-coated member for intercepting mobile portions of the liquid occasioned by the contact between the coated contact member and the fixed member's contact surfaces.

7. In a mercury-contact switch including a plurality of fixed contact members and a mercury-coated contact member adaptable for contacting a preselected fixed member, baffle means associated with the mercury-coated member for intercepting the flight of portions of the mercury toward the regions between the fixed contact members.

8. A liquid-contact switch comprising: a movable contact element having a coating of an electrically conductive liquid thereon; a plurality of fixed contact elements arranged in spaced-apart relation with respect to each other and to the movable element, each fixed element including thereon a plurality of spaced-apart contact surfaces, the contact surfaces being wettable by the liquid and the fixed elements' remaining surfaces being essentially unwettable by the liquid; means for moving the movable element into contact with the contact surfaces of any of the fixed elements; and additional means for trapping flying portions of the liquid.

References Cited in the file of this patent

UNITED STATES PATENTS

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