Dec. 8, 1959 L. W. COOK ET AL 2,916,589

MERCURY BUTTON SWITCH WITH RESILIENT SEAL

Filed June 2, 1958 2 Sheets-Sheet 1

Fig. 1.

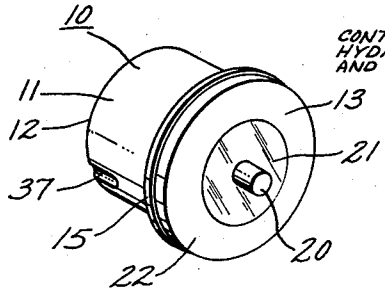


Fig. 2.

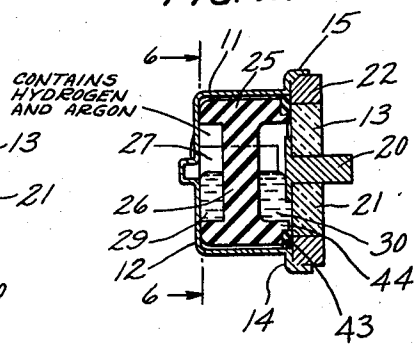


Fig. 3.

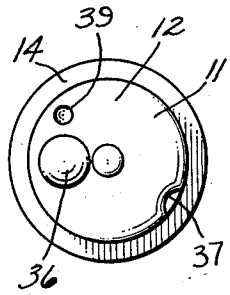


Fig. 4.

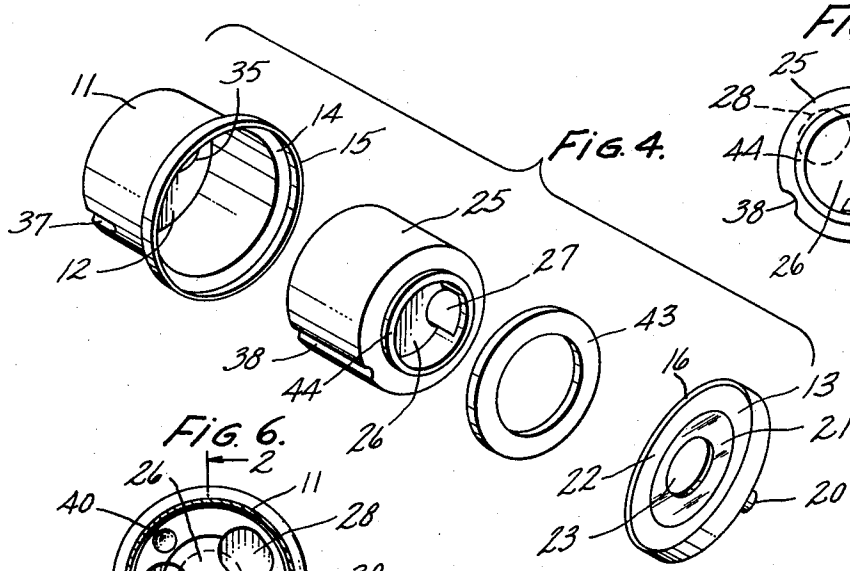


Fig. 5.

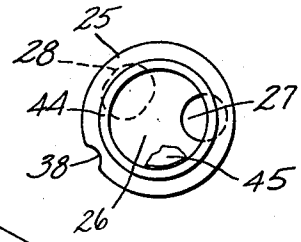


Fig. 6.

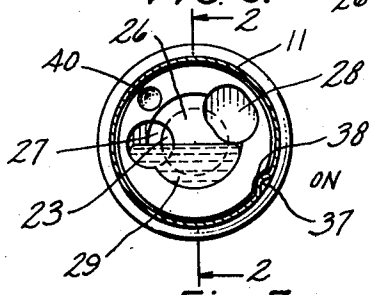
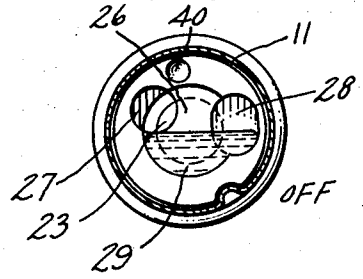


Fig. 7.



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FIG. 8.

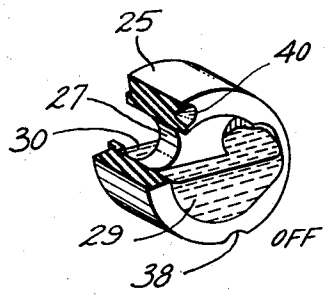


FIG. 9.

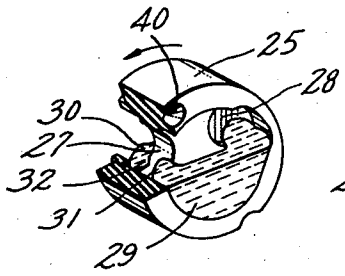


FIG. 10.

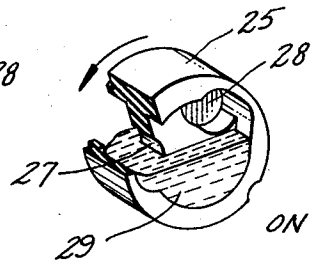
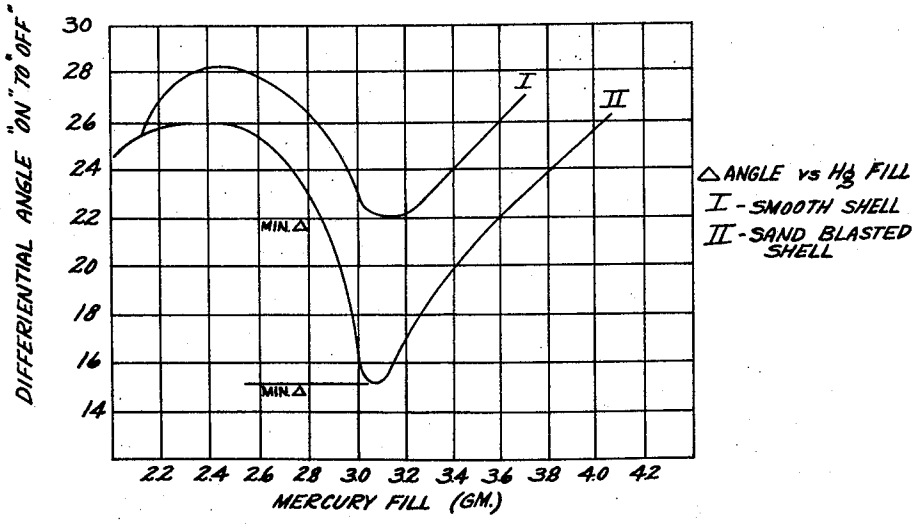


FIG. 11.



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MERCURY BUTTON SWITCH WITH RESILIENT SEAL

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Application June 2, 1958, Serial No. 739,305

17 Claims. (Cl. 200—152)

The present invention relates to liquid contact switches and particularly to an improved mercury button switch of the type which are widely used for controlling residential lighting circuits.

The vast majority of mercury button switches have been manufactured according to the teachings in the Payne Patent No. 2,101,093, Walker Patent No. 2,101,115 and a later Payne Patent No. 2,177,498. All of these patents are assigned to the same assignee as is the present invention. Such mercury button switches of the prior art have included a ceramic barrier sandwiched between a pair of hat-shaped metal shells of chrome-iron. The assembly was hydrogen filled at a pressure of approximately three atmospheres, and hermetically sealed by a glass ring encircling the rims of the shells and bonded to the periphery of the ceramic barrier. A small opening is formed through the barrier at a point that is radially offset from the geometric center of the barrier, which center coincides with the pivotal axis of the button. A quantity of mercury is included in the button as a liquid contact medium for electrically connecting the two metal shells to close the switch circuit. This is accomplished when the button is rotated to dip the through opening in the barrier into the mercury so that the mercury that was once separated into two pools by the barrier will flow through the opening and merge into one body of mercury. To open the circuit, the procedure is reversed and the button is rotated in the opposite direction to lift the through opening out of the mercury, thereby electrically isolating the mercury into two separate pools.

Extreme care is taken to clean the switch parts before assembly so that the mercury will not become contaminated and sluggish during the expected life of the switch. Welded on the inner end surface of each metal shell is a small platinum tab which is not appreciably affected by oxidation during the fusion of the glass ring around the periphery of the switch. Unfortunately, the glass will not seal to the metal shells unless the metal is first coated with an oxide. The purpose of the platinum has been to insure a low-resistance electrical path between the mercury and the metal shells. After the mercury button is completely assembled, it is subjected to a low current, high voltage activation for a short period of time which cleans up the internal surfaces of the shells.

The prior art mercury button switches appear to be very simple in design, but they present many difficult manufacturing problems. Probably the most serious problem has been in forming the three component hermetic seal between the glass ring, the metal shells and the ceramic barrier. The ingredients which constitute the ceramic barrier are mainly clay and magnesia held together by a suitable binder. It has been extremely difficult to control the ceramic barrier so that its coefficient of thermal expansion will be substantially equal to that of the metal shells and the glass seal. This is a critical factor which affects the dimensions of the mating

parts during the firing of the metal shells until they are red hot so that the glass ring will melt and shrink around the shells and the barrier. It should be understood that the prior art mercury buttons mentioned above have performed exceptionally well in the field once they have passed the rigid quality control examinations that are performed in the factory. Unfortunately, there has always been a high rejection rate of these mercury buttons, which has held the price of these switches to a premium over the price of standard toggle switches.

The design of the present invention is a further improvement over the invention in the copending application of Cook et al., Serial No. 601,396, (now abandoned), which are filed August 1, 1956, and was likewise assigned to the same assignee as is the present invention. As in the copending application, this invention was also made to eliminate the three component seal between the glass, the metal shells, and the ceramic barrier. The mercury button of the present invention has demonstrated in the laboratory the ability to withstand the same A.C.-D.C. and tungsten load tests that are performed by the Underwriters' Laboratories for a vastly increased number of cycles over the design of the Cook et al. application. Thus, this switch can be given a higher electrical rating for a design which is the same or lower in cost than previous mercury button switches. This not only broadens the field of application for this switch but renders the switch more reliable for the majority of uses to which it will be applied.

The principal object of this invention is to provide a compact mercury button switch with a minimum number of parts that may be assembled automatically and sealed into a hermetic enclosure.

A further object of this invention is to provide a simple design for a mercury button switch having a metal enclosure with an insulated through terminal in one end, and an interior with a reduced surface friction acting against the flow of the mercury.

A further object of this invention is to provide a mercury button switch with a dielectric liner for opening and closing the electrical circuit through the mercury, and with a resilient seal interposed between the liner and an end cover of the switch enclosure.

A further object of this invention is to provide a rim on the end of the liner of the switch to protect a resilient rubber seal from the intense heat of the arc that is struck during the operation of the switch.

A further object of this invention is to provide a mercury button switch with a reservoir strategically located in the dielectric liner to increase the kinetic energy of the moving mercury bodies during both the opening and closing of the circuit.

A still further object of this invention is to provide a mercury button switch with a low pressure composite gas fill that will preserve a relatively low arc voltage across the bodies of mercury at the instance of first closure and rebound of the separate mercury pools.

A further object of this invention is to provide a mercury button switch with a composite gas fill of a chemically inert gas and a chemically active gas, the two gases having dissimilar but desirable dielectric characteristics to minimize the arc voltage across the bodies of mercury and to retain the purity of the mercury from contamination by the decomposition of the switch elements.

A further object of this invetnion is to provide the switch with a strategically located noble metal of proper size which will amalgamate with the mercury and is located to exert a force in addition to the gravity force acting on the mercury as the switch is turned to render the switch consistently reliable.

A further object of this invention is to provide a double anchorage for the dielectric liner within the metal en-

closure of the switch to eliminate relative movement between the parts.

A still further object of this invention is to provide a switch with an inclined surface within the metal switch enclosure to redirect the arc away from the source of the arc.

The preferred embodiment of the present invention incorporates a cylindrical metal shell or cup having an open end through which the internal switch elements are assembled. This open end is provided with a circular flange having a rolled-over edge to form a pocket in which a separate cover plate is received and welded in place. The cover plate includes a central insulating window with an external switch terminal extending therethrough; the terminal having an enlarged inner end flattened against the inenr side of the cover plate and partially immersed in a pool of mercury. The main portion of the interior of the switch enclosure represents a dielectric liner of tubular shape which fits within the metal shell and has a central transverse partition that divides the mercury into two pools when the switch is in its Off position. This partition is supplied with a through opening so that the two mercury pools may merge when the switch is rotated about its geometric center axis to move the through opening below the level of the mercury. A resilient seal in the form of a rubber washer extends around a circular rim formed at one end of the liner nearest the cover plate. This washer is compressed between the insulating window of the cover plate and the liner when the plate is welded to the metal shell. This seals insures the complete electrical isolation of the mercury from the metal portion of the cover plate that encloses the insulating window for the end terminal.

The central partition of the dielectric liner includes a reservoir or cavity in at least one face thereof to increase the kinetic energy of the mercury in both directions of movement during the opening and closing of the circuit. This reservoir is strategically located so that as the two pools of mercury begin to merge, the mercury in the reservoir will be dumped suddenly to overcome any local explosive effects as the contacting surfaces of mercury suddenly allow current to flow through the switch. The reverse action is also beneficial for when the two pools begin to separate the mercury seems to pour back into the reservoir to assist in the rapid separation of the mercury and the interruption of the circuit. It has been found beneficial to lower the friction between the mercury and the interal surfaces of the mercury button so as to increase the fluid characteristics of the mercury. This has been done by roughening the surface of the liner as well as the inner surface of the metal shells. Accordingly, the area of contact between the mercury and the internal surfaces of the switch have been reduced, thereby reducing the friction or adhesion between the bodies. Also, the action of the mercury can be improved by establishing an anchor point for the mercury pools, off balance so to speak, so that they are urged to move by forces greater than the force of gravity alone. A small deposit of silver appropriately placed on the surface of the partition will amalgamate with the adjacent mercury pool to provide an anchor point midway between the two extreme positions of the switch to hold to a minimum the angular rotation of the switch handle. It has also been found advantageous to use a low pressure composite gas fill within the button. A mixture of hydrogen and argon gas has been found most satisfactory for reasons which will be explained hereinafter.

Our invention will be better understood from the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

Figure 1 is an isometric view showing a mercury button switch embodying this invention.

Figure 2 is a cross-sectional elevational view taken through the center of the switch on line 2—2 of Figure 6.

Figure 3 is a left end view of the switch of Figure 2.

Figure 4 is an exploded isometric view of the various parts of the switch which confine the mercury and form a complete assembly.

Figure 5 is a right end view of the dielectric liner which fills most of the interior of the switch enclosure and serves to control the flow of mercury during the operation of the switch.

Figure 6 is a cross-sectional elevational view taken on the line 6—6 of Figure 2, with the removal of the closed end of the metal shell to observe the position of the mercury as the switch is rotated counterclockwise to the On position.

Figure 7 is a cross-sectional elevational view similar to that of Figure 6 after the switch has been rotated clockwise to its Off position.

Figures 8, 9 and 10 are isometric views showing the dielectric liner and the mercury as the mercury would be confined in the metal enclosure, although the enclosure is not shown.

Figure 8 representing the Off position of the switch.

Figure 9 showing the mercury as the two pools enter the through opening in the partition of the dielectric liner, but before the pools merge into one.

Figure 10 is a later view showing the switch in the On position.

Figure 11 is a graph showing the relation between the number of grams of mercury in the switch versus the throw of the switch trigger or the differential angle between the On and the Off positions for two switch samples.

Referring in detail to the drawing, and in particular to Figures 1 and 4, **10** represents the completely assembled mercury button switch embodying this invention. The switch has a metal enclosure formed by a cylindrical shell **11** that has a closed end **12** and an open end that is closed by a separate cover plate **13** welded to the shell. The open end of the shell **11** has an outwardly extending flange **14** that has its outer edge rolled over at **15** to establish the flange **14** as a recessed seat for supporting the cover plate **13** in a centered position prior to the welding operation. The inner face of the cover plate **13** has a welding projection **16** around the rim of the plate which is melted during the projection welding process to form a hermetic seal between the shell **11** and the cover plate **13**.

The metal shell **11** constitutes one electric terminal of the switch and the second terminal is a metal pin **20** which extends through a glass window **21** in the central portion of the cover plate **13**. The cover plate **13** is an annular metal ring **22** with its center window filled by a compression sealing process with a Pyrex type glass **21**. The innermost end **23** of the terminal **20** lies as if it were flattened against the inner side of the glass window **21**, and it is much larger in diameter than the diameter of the pin, as is best seen in Figure 2.

The principal element of the switch is a dielectric liner **25** of ceramic material that is of tubular shape and closely interfits within the metal shell **11**. The liner **25** has a transverse central partition **26**, as best seen in Figure 2, which serves to divide the enclosure into two compartments for retaining the mercury. Looking at the left end cross-sectional views of Figures 6 and 7, the partition **26** is shown with a circular through opening **27** and a reservoir or cavity **28** in only one side of the partition. The through opening **27** is designed to permit the mercury on both sides of the partition to flow together at the center of the opening and complete an electrical circuit between the metal shell **11** and the head **23** of the terminal pin **20**. It is important that a button, to be usable in a wall-mounted switch, must be capable of operation in less than a maximum angle of throw on the order of 20° from an On position to the Off position. Accord-

ingly, the through opening 27 is located as far as possible away from the geometric center axis of the metal shell, as is shown in Figure 6. This establishes the through opening 27 not only through the partition 26 but also through the tubular portion of the liner 25.

There is an important reason for establishing the reservoir or cavity 28 in one side of the partition 26. It is strategically located with its lower edge on a line drawn through the center axis of the shell and the center axis of the through opening 27, as shown in Figure 6. Turning now to Figures 9 and 10, as the switch is rotated in a counterclockwise direction, the through opening 27 will begin to sink below the top level of the mercury pools 29 and 30. This begins to remove the obstruction between the two pools and they start slowly to enter the through opening 27 with rounded frontal surfaces 31 and 32, respectively, as depicted in Figure 9. As these two bodies of liquid mercury come into contact, a high inrush current will immediately vaporize the frontal surfaces of the mercury bodies. Final circuit closure might occur only after two or more such vaporizations or explosions. The purpose of the reservoir is to dump the last traces of mercury out of the reservoir and into the mercury stream at the opportune moment when the two pools of mercury begin to merge at the center of the through opening 27. This dumping action will increase the kinetic energy of the moving mercury bodies and deter the local explosive effects of the contacting surfaces of mercury. When the switch is turned in the opposite direction, the reservoir 28 again serves to increase the kinetic energy of the moving mercury bodies as they begin to separate. The reservoir performs this function by absorbing a quantity of mercury just at the opportune time when the two bodies of mercury separate from each other.

There is a dimple 35, in line with the through opening 27, pressed into the inner surface of the closed end 12 of the metal shell. The dimple is shown as an embossment 36 in the left-hand end view of the shell in Figure 3. The purpose of the dimple is to provide an inclined surface to redirect the arc from the source of the arc through an extended path of cooling gas atmosphere.

In operation, a switch handle (not shown) is seated on the outer cylindrical side of the shell 11 to oscillate the button structure about the central axis of the shell between an On and an Off position. The switch handle must be in driving engagement with the shell so that movement of the handle will move the button. This driving engagement is created by a short indentation 37 pressed inwardly of the shell and lying parallel to the central axis of the shell for receiving a projection on the bottom of the switch handle, as is well understood by those skilled in this art. There not only must be a particular alignment between the switch handle and the metal shell; there must also be alignment between the metal shell and the ceramic liner 25. This is absolutely necessary since the liquid mercury always seeks its own horizontal level within the liner. Accordingly, the through opening 27 in the partition of the liner must be accurately positioned with respect to the level of the mercury for obtaining the minimum angle of throw. Hence, the indentation 37 is used for a second purpose, that of indexing the ceramic liner 25, as seen in Figures 4 and 6. The liner 25 has a longitudinal groove 38 which receives the inward projection of the indentation 37 of the metal shell, as best seen in Figure 6. The indentation is made short so that the liner may be first positioned in the shell by an automatic assembly machine, and then turned until the groove 38 aligns itself with the indentation 37 to permit further entry of the liner within the shell.

The button of the present invention is designed to be substantially the same size as the buttons of the prior art. Also, the button is to be incorporated in switch housings of standard size which are in turn covered by standard faceplates having a rectangular opening for the switch handle. In practice, the switch handle has a maximum throw from On to Off of approximately 40° before it strikes the edge of the opening in the faceplate. There are however several uncontrollable variables that may arise and have a cumulative result to change the operating conditions of this switch. First, if too little or too much mercury is poured into the button the throw of the button will be increased. Secondly, the contamination of the mercury will have a similar result. Thirdly, if the contacts within the switch housing or the mounting strap for the switch are misaligned, the button will be cocked at an undesirable angle and its characteristics will change. Fourthly, if the wall or the switch box within the wall is not perpendicularly arrranged with respect to a horizontal plane, the switch and hence the button will be leaning at an angle to the horizontal. Accordingly, a decision has been made to limit the maximum throw of the button to a maximum of 20° to accommodate the many variables mentioned above so as to provide a switch that will operate consistently within a permissible angle of 40°.

There is always a certain amount of looseness between the liner and the shell in order to avoid a forced fit which might crack the ceramic material during the assembly. This looseness, however, tends to vary the operating angle of the switch handle with respect to a horizontal plane. It will be understood that if the throw of the handle is excessive, the handle will strike the end of the opening in the faceplate before the switch is operated, thus preventing its operation. This loose fit between the liner and shell has been retained during the assembly of the liner, but it has been eliminated when the liner is finally assembled by the use of a slight embossment 39 in the end wall 12 of the shell which is shown from the back in Figure 3. This embossment mates in a conical hole 40 in the adjacent edge of the tubular liner 25. This embossment 39 and mating conical hole 40 are generally diametrically opposite the indexing arrangement formed by the groove 38 and the indentation 37 of the shell as shown in Figure 6. These two interfitting arrangements between the ceramic liner 25 and the metal shell 11 substantially prevent any relative movement between the two elements, once the switch is assembled.

A critical factor, that was discovered after innumerable sample testing and design changes, is the necessity for a tight seal between the ceramic liner 25 and the glass window 21 of the cover plate 13. The terminal pin 20 constitutes one terminal of the switch while the metal shell 11 and annular ring 22 of the cover plate 13 form the second terminal. If a reliable seal between the mating surfaces of the liner 25 and the glass window 21 is lacking, minute droplets of mercury will penetrate this area and cause unplanned and unwanted closure of the circuit from the flattened head 23 of the terminal pin to the metal ring 22 of the cover plate. The normal dimension tolerances for the ceramic liner, the glass window and the metal shell make it improbable that a direct engagement of the ceramic across the inner face of the glass and the metal ring will ever seal this area from the penetration of high energy mercury vapors which are created as the switch operates. The ceramic liner which is required to seal against the glass window depends for sealing pressure on the following part dimensions:

(1) The depth of the drawn metal shell 11.

(2) The height of the welding projection 16 around the rim of the metal cover plate 13.

(3) The volume of metal that is melted in the projection welding process.

(4) The level of the inner face of the glass 21 as it is sealed to the metal ring 22 of the cover.

(5) The length of the tubular ceramic liner 25. Dimensional variations in items 1, 2 and 3 above can be controlled within reasonable limits by using careful man-

ufacturing procedures. The dimensions of items 4 and 5 above can never be controlled precisely, regardless of manufacturing process. In item 4 above it is imperative that the inner surface of the glass and the metal ring 22 be in the same plane, precisely, if a non-resilient ceramic liner is to seal securely. When glass is melted and bonded to the metal ring, a meniscus is formed in the glass which is concave. This meniscus may form to the flat side of the metal ring or may fall short of this position, depending on the many uncontrollable variables involved in processing the compression seal of the glass within the metal ring. A few of the uncontrollable variables would be the firing temperature and rate of change of temperature in the furnace, the atmosphere in the furnace, dimensions of glass preform, density and particle size of glass preform, size of the opening in the metal ring, and density and distribution of the oxide film within the metal ring opening.

Similarly, in item 5 above the length of the tubular ceramic liner is variable for the following reasons:

(1) Chemical purity of the ceramic powders.
(2) Proportions of, and characteristics of the ceramic fluxing material.
(3) Rate of temperature change in firing the ceramic.
(4) Atmosphere in the furnace.
(5) Position of the parts on the firing saggers.
(6) Original unfired dimensions of the pressed parts.
(7) Density of the unfired parts.
(8) Granular structure of the fired parts.

The above technical obstacles to a reliable non-resilient seal between the ceramic liner 25 and the inner face of the cover plate 13 have fostered the use of a resilient annular seal or washer 43 of special design that is compressed between these parts, as shown in Figures 2 and 4 of the drawings. The most satisfactory material that has been used to date for this washer 43 has been silicone rubber, although several less temperature-resisting materials such as natural rubber have also been found acceptable. The silicone washer 43 is approximately .030" thick and the engaging parts are designed to compress this rubber about 50% or .015" under conditions of the nominal values of all dimensions. Thus, wide variations in part dimensions are possible without diminishing the effective seal at the inner face of the cover plate 13. This washer, however, will be positioned near the through opening 27 in the partition 26. This area is subject to intense local heating when the switch is operating at its full load capacity. We have discovered that a narrow projecting rim or flange 44 on the end of the tubular liner 25 is most effective in screening the high temperature arc from the silicone washer. This rim 44 is substantially equal in internal diameter to the smallest diameter of the tubular liner, as is best seen in Figure 4. The washer 43 slips closely over the rim 44 so that when the cover plate 13 is welded to the recessed flange 14 of the metal shell, the washer will not be allowed to expand inwardly into the chamber of the switch in which the mercury is present, as seen in Figure 2. There is only a very slight air gap or clearance between the circular end of the rim 44 of the liner and the glass window 21 that separates the mercury chamber from the silicone washer, but this has caused no deterioration of the resilient seal in the exhaustive tests that have been performed to date.

An additional improvement which has been incorporated in this new mercury button is a low pressure composite gas fill. In this particular design we have found that the use of high pressure hydrogen fill gas alone on the order of three or more atmospheres, as used in the previous buttons, is undesirable. It is true that the hydrogen gas has a distinct advantage in absorbing and dissipating the heat of the electrical arc. It has a further advantage in being chemically active to combine with any impurities liberated by the electric arc, particularly impurities which might be absorbed by the bodies of mercury to depreciate their active fluid characteristics. The energy in an electrical arc is determined by the current through the arc and the voltage across the arcing contacts. In any switching device arcs become destructive when the product of arc current and arc voltage exceed a critical limit. Hydrogen, by its nature, has a very high dielectric recovery rate. At any instant after the zero of current this recovery rate or strength is several times greater in hydrogen than it is in other common gases. Electrical contacts separated in hydrogen therefore experience this effect in the form of high arc voltages. In other words, the high dielectric recovery of hydrogen atmospheres increases the energy developed between two contacts that interrupt electrical currents in such a medium. As the pressure of the hydrogen gas is increased the dielectric recovery strength also increases as does the arc energy.

High values of arc energy are desirable as two electrical contacts are operated to open or break an electrical circuit, because these high energy levels cannot be sustained by the power source and the arc is extinguished by its own greed. However, the reverse is true in closing or making an electrical circuit; particularly with mercury circuit closures. High arc energy levels are undesirable because they contribute to multiple explosions and rebounds of the mercury pools before the circuit is established. Therefore hydrogen at high pressures is now deemed by the applicants as being undesirable in mercury switches, which is contrary to the theory followed in making the prior art buttons.

In an alternating current switch, best advantage can be made of the device if the circuit is opened and closed during the periods when the voltage and current values pass through zero. This factor becomes increasingly important when the circuit closing is accomplished by liquid contact such as liquid mercury. In a high inrush current circuit such as produced by a tungsten lamp load, it is improbable that the two pools of liquid mercury will close at a near peak of the current cycle without causing local heating that explodes or vaporizes the frontal surfaces of the mercury bodies. Such an explosion opens the electrical circuit and requires a continued motion of the mercury pools to effect a second circuit closure. When a hydrogen atmosphere alone surrounds the mercury pools, the heat of the first explosive contact of the mercury bodies is rapidly dissipated by the hydrogen, and the excellent recovery characteristics of the gas almost instantly reestablish full line potential across the bodies of mercury which have been separated by the explosion. A second closure of these mercury pools will, therefore, occur at a voltage as great as the original closure and a second explosion is almost certain to result. It should be noted that the local explosions here described are of atomic proportions, and are not evident externally of the mercury button. Similarly, the mercury vaporized during such explosions is confined within the button assembly and quickly condenses so that there is no permanent loss of mercury fill.

The above circuit closure conditions can be avoided, particularly on high alternating current loads with the introduction into the button, in addition to the hydrogen, of an inert fill gas which has a particularly poor dielectric recovery strength characteristic. Both argon and neon are such gases. When the argon gas is used, the first explosion of the mercury pools vaporizes some mercury and separates the bodies of mercury, but the argon gas immediately ionizes and preserves a relatively low arc voltage across the bodies of mercury. Then as the mercury pools reclose, the low arc voltage across the mercury assures a low energy closure without secondary explosions. A hydrogen filled switch usually continues reclosures until by chance a near zero point in line voltage occurs at the time of closure. The argon hydrogen

fill gas provides nearly this condition at any instant of reclosure. We have found with repeated testing that a proper proportion of argon and hydrogen fill gas at a pressure of about 10 lbs./sq. in. gauge results in a smaller angle of throw for the switch handle and also causes less destruction within the button due to repeated arcing on each switching cycle.

Our development efforts have also discovered the importance of a "soft" anchor point for the mercury to make the angular operation of the switch consistently reliable. Such an anchor point can be established by the deposit of a small amount of silver or other noble metal **45**, in Figure 5, to the surface of the partition **26** of the liner so that the silver will amalgamate with the adjacent mercury pool to provide a temporary restraint for the mercury midway between its at-rest positions On and Off until the mercury overcomes the restraint and moves rapidly to catch up with itself in point of time. The force of coalescence between the spot of amalgamation, and the center of gravity of the mercury pool can be determined to aid the gravity force on the mercury in effecting a consistent and stable operating angle as the button cycles between On and Off positions. It is apparent that if the anchor point is made very large and very secure, the anchor forces will completely exceed the forces of gravity on the mercury pool and no switch action will occur when the switch is rotated.

An additional feature of this new design is a reduction in the friction forces acting on the mercury pools. It is desirable that the mercury be free moving and be devised for ready movement with the least amount of external energy; i.e., angular movement of the switch handle. The friction forces or adherence of the mercury to the ceramic liner and metal shell can be reduced if the surface area between the mercury and these parts can be reduced. This is accomplished by roughening the parts. In the case of the ceramic liner, the roughness can be developed easily by fabricating the part from coarse ceramic powders. The metal parts in turn can be roughened by sandblasting or chemical etching. The mercury pools when clean have high surface tension to prevent the liquid mercury from assuming an irregular surface that would be the image of the adjacent metal or ceramic. In other words, the smooth mercury rests only on the rough points of the supporting bodies. The contact area between the mercury and the supports is, therefore, considerably reduced from the condition where the supports have a glass smooth finish.

This action is quite evident in the graph of Figure 11 where the grams of mercury fill represent the abscissa of the graph while the ordinate is the differential angle between the extreme On and Off positions. Curve I represents a design with a smooth shell. The differential angle of the switch handle is much greater at a given mercury fill than in the situation of curve II where the shell has been roughened by sandblasting. It is readily seen that the inclusive angle from On to Off positions of the button has been reduced from a low of 22° on the smooth surface to 15° on the rough sandblasted surface. No other changes were made to obtain the findings of the two curves; in fact, they were the identical parts and conditions used in both. It is also evident from this graph that the mercury fill is directly dependent on the size and position of the reservoir **28**, as mentioned previously. In the lower fills of curves I and II, the reservoir is not being used at all and the mercury merely pours into and out of the through opening **27**. At a point of around 3.1 grams, the reservoir is being used to best advantage when it is dumping the mercury into the through opening at the instant of circuit closure, and also in reverse at circuit interruption. In the higher fills, above 3.3 grams, the reservoir again is not advantageous; that is, the mercury mass is so large that it pours into the reservoir before breaking the circuit. In the higher fills, the reservoir remains full during normal rotation of the button and has no effect on lowering the differential or operating angle of the switch handle. Such a study as depicted by this graph is of great assistance in developing consistent operating angles in a mercury button with a minimum mercury fill.

Having described above our invention of a novel mercury button switch with a metal enclosure, it will be readily understood by those skilled in this art that this design is well engineered so that it can easily be duplicated and assembled by automatic machinery with a negligible amount of human handling and supervision. This design represents the culmination of a tireless and expensive research and development program that has extended over a several year period after countless theories, tests and design changes, and numerous consultations with fellow scientists in all of the related branches of this art who might shed some light on the mysterious nature of mercury as an electrical contact medium. It is conceivable that other resilient seals could be substituted for the silicone washer. One possibility is a circular metal sheet that would be held tightly against the end of the liner by pressure exerted at the center of the sheet by the inner end of the terminal pin to give an "oil can" effect.

Modifications of this invention will occur to those skilled in this art and it is to be understood, therefore, that this invention is not limited to the particular embodiments disclosed but that it is intended to cover all modifications which are within the true spirit and scope of this invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A mercury button switch comprising a cylindrical metal shell having a closed terminal end and an open end, a cover plate hermetically sealed over the open end of the shell, the cover plate including an insulated window with a switch terminal extending through the insulation and being insulated from the cover plate, a cylindrical liner of insulating material assembled in the shell, the liner including a central transverse partition, the partition having a through opening and a reservoir in at least one side thereof, the lower extremity of the reservoir being above the mercury when the switch is closed, a precise amount of mercury contained in the shell with the partition dividing the mercury into two pools in the Off position of the switch, the switch being oscillated about the center axis of the shell to change the position between the On and Off positions, the two pools of mercury being joined in the through opening of the partition when the switch is in the On position, the mercury being dumped from the reservoir as the mercury pools begin to merge, while a quantity of the mercury is absorbed by the reservoir as the mercury is being separated within the through opening so as to increase the kinetic energy of the moving mercury bodies, the inner end of the terminal assembled in the cover plate being immersed in the mercury, a sealing means between one end of the cylindrical liner and the terminal insulation to insure a tight seal at the inner face of the cover.

2. A mercury button switch as recited in claim 1 wherein the end of the liner that engages the seal has a circular rim adjacent the internal diameter of the liner, the seal being resilient and assembled around the rim and compressed between the liner and the terminal insulation so that the seal will be protected from the high temperature arc that is formed upon closure of the mercury pools.

3. A mercury button switch as recited in claim 2 wherein the seal is a thin resilient washer of high temperature resisting material that forms a compression seal around the rim.

4. A mercury button switch as recited in claim 2 wherein the seal is provided by a thin silicone washer that is shielded from high temperature arcs by a circular

rim on the end of the liner which closely fits within the center of the washer.

5. A mercury button switch as recited in claim 1 wherein the terminal that is assembled in the insulating window of the cover has an enlarged inner end of generally circular shape that lies flattened against the inner face of the window.

6. A mercury button switch as recited in claim 1 with the addition of a relatively low pressure composite gas fill comprising hydrogen which has a reduced dielectric recovery rate on an alternating current circuit due to the low pressure, and an inert gas such as argon which inherently has a poor dielectric recovery characteristic, the composite gas fill serving to reduce the arc energy and hence the number of rebounds of the mercury pools before the circuit is finally closed, the hydrogen serving to react chemically with impurities that might contaminate the mercury pools.

7. A mercury button switch as recited in claim 1 wherein the inner surface of the entire outer enclosure has been roughened thereby lowering the friction encountered between the containing walls and the mercury to obtain a consistent angle of operation during the opening and closing of the circuit.

8. A mercury button switch as recited in claim 1 wherein a small deposit of noble metal is attached to at least one side of the partition of the liner, slightly spaced from the through opening in the partition to amalgamate with the adjacent mercury pool and serve as a temporary restraint or anchor point for the mercury midway between its extreme On and Off positions to be added later to the force of gravity acting against the mercury in effecting reliable operation of the switch.

9. A mercury button switch as recited in claim 8 wherein the noble metal is applied as a small amount of silver paint to one side of the partition of the insulating liner.

10. A mercury button switch comprising a cylindrical metal shell having a closed terminal end and an open end that is closed by a cover plate that is hermetically sealed over the open end, the cover including a central terminal that extends through the cover and is sealed in a glass window, a cylindrical liner of ceramic material assembled in the shell, the liner including a transverse partition having a through opening of such size as to allow the passage of mercury therethrough, a reservoir in at least one side of the partition, the lower extremity of the reservoir being generally above the lower half of the through opening when the switch is closed, a measured amount of mercury contained in the shell so that in the Off position of the switch the partition divides the mercury into two pools of equal volume, the shell being rotated about its central longitudinal axis to dip the through opening below the mercury so that the two pools will flow together in the On position of the switch, the mercury being dumped completely from the reservoir at the precise moment when the mercury pools begin to merge, while a quantity of mercury is absorbed by the reservoir just at the precise moment that the mercury is being separated within the through opening so as to increase the kinetic energy of the moving mercury bodies, the end of the cylindrical liner nearest the cover having a circular rim adjacent the smallest diameter of the cylinder, and a resilient washer assembled around the rim, the washer being compressed between the end of the liner and the glass window in the cover when the cover is sealed to the shell, the inner end of the terminal extending through the cover being larger than the cross-section of the terminal, and also being flattened against the inner face of the glass window, at least the lower half of the inner end of the terminal being immersed in the mercury, and a low pressure composite gas fill of hydrogen and argon, the hydrogen gas serving to absorb and dissipate the heat of the electrical arc that is struck during closure of the switch as well as to combine with any impurities liberated by the arc, the argon tending to preserve a relatively low arc voltage across the bodies of mercury upon switch closure to assure a low energy closure without secondary explosions.

11. A mercury button switch as recited in claim 10 wherein the ceramic liner is fabricated from coarse ceramic powders and the inner surface of the closed terminal end of the shell is roughened to reduce the friction encountered by the mercury with both the ceramic and metal parts.

12. A mercury switch comprising a metal enclosure with two terminals insulated from each other, a body of mercury within the enclosure, and a dielectric partition for separating the mercury into two pools in the Off position, the turning of the button causing the mercury to merge thereby closing an electrical circuit, the enclosure being filled with a relatively low gauge pressure of about one atmosphere of composite gas of hydrogen and an inert gas such as argon, the gas fill serving to reduce the arc energy and hence the number of rebounds of the mercury pools before the circuit is finally closed, the hydrogen serving also to react chemically with impurities that might contaminate the mercury pools.

13. A mercury button switch comprising a metal enclosure containing a body of mercury and having two terminals insulated from each other, a transverse dielectric partition fixed within the enclosure for separating the mercury into two pools in the Off position of the switch, the enclosure being filled with a relatively low gauge pressure of about one atmosphere of composite gas of hydrogen and an inert gas such as argon, the gas fill serving to reduce the arc energy, a through opening extending through the partition so that when the button is rotated the opening will dip below the level of the mercury and allow the mercury to flow therethrough, a reservoir formed in at least one side of the partition for receiving some of the mercury when the circuit is broken through the mercury, the lower extremity of the reservoir being above the level of the mercury when the circuit is closed by the mercury, the mercury being dumped completely from the reservoir at the precise moment that the two mercury pools first merge, while a quantity of the mercury is absorbed by the reservoir at the precise moment that the mercury is being separated within the through opening so as to increase the kinetic energy of the moving mercury bodies.

14. A mercury button switch as recited in claim 13 wherein the reservoir is in the form of a relatively deep cavity that tends to retain the mercury therein until the rotation of the button lifts the lower extremity of the reservoir above the level of the mercury at which time the mercury will both flow into the through opening and when the two pools begin to merge the reservoir will dump the last traces of the mercury.

15. A mercury button switch comprising a metal enclosure formed by a cylindrical metal shell having a closed end and an open end that is closed by a hermetically sealed cover plate, the cover including a central terminal that extends through the cover and is sealed in a glass window, a cylindrical liner of ceramic material closely fitted within the enclosure, a short indentation pressed into the outer surface of the shell near the closed end and extending parallel to the central axis of the shell, the outer surface of the liner having a groove the length of the liner that is adapted to be engaged by the indentation of the shell, the inner surface of the closed end of the shell having a small projection that extends into a conical recess in the end of the liner, this projection being on the opposite side of the shell from the short indentation to provide an accurate double anchorage for the liner with respect to the shell and prevent relative movement therebetween.

16. A mercury button switch with a metal enclosure and a ceramic partition with a through opening for the flow of mercury, the portion of one end of the metal

enclosure that is in line with the through opening being inclined in a direction away from the through opening so that when an arc is struck within the opening and it strikes the inclined portion of the enclosure the arc will be directed away from the source of the arc and assume an extended path and be cooled for early extinguishment of the arc.

17. A mercury button switch as recited in claim 16 wherein the metal enclosure contains a low gauge pressure of about one atmosphere of composite gas fill of hydrogen and argon, and the partition includes a reservoir in at least one side but located on the opposite side of the pivotal axis of the switch from the through opening, the lower extremity of the reservoir being on a substantially straight line drawn through the pivotal axis of the switch and the center of the through opening, the reservoir also being above the level of the mercury when the circuit is closed.

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