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HIGH LOAD MERCURY SWITCH

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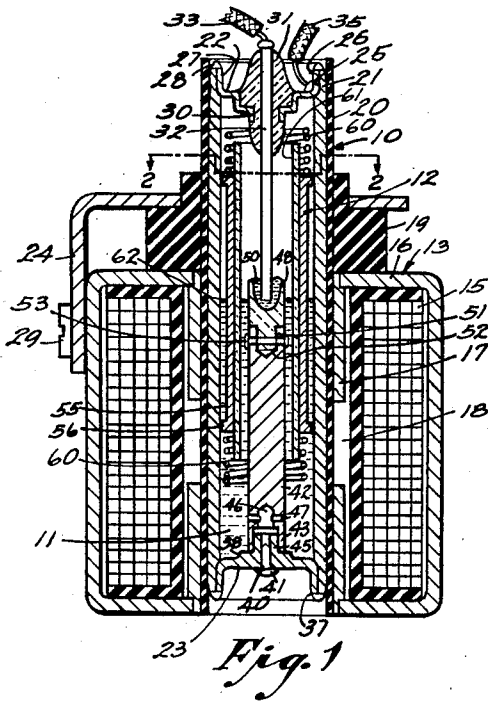
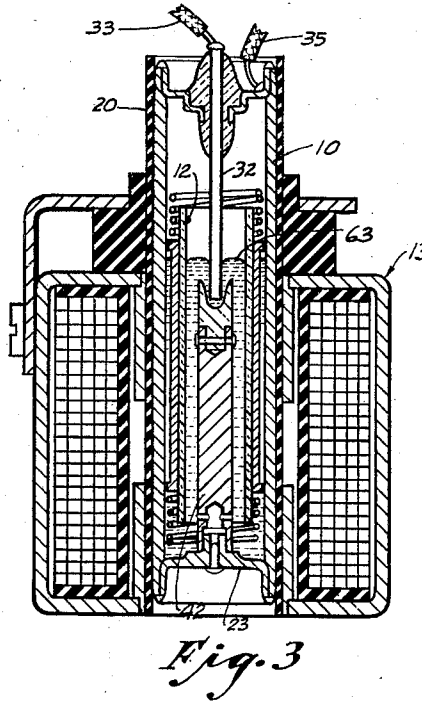
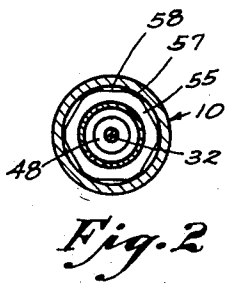
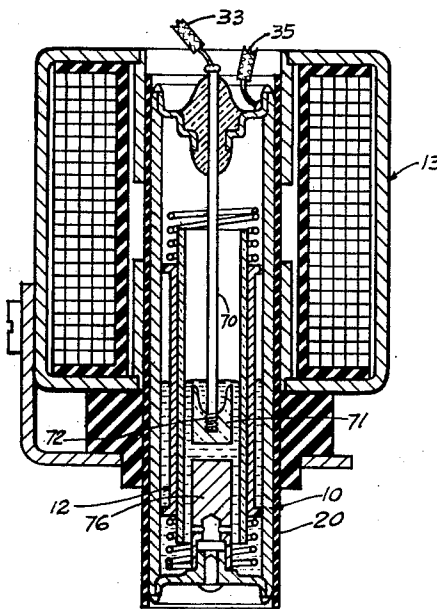
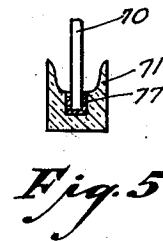


Fig. 4

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HIGH LOAD MERCURY SWITCH

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The principal object of this invention is to increase the life and current carrying capacity of mercury switches, particularly those of the metal envelope, mercury displacement type. Heretofore, a switch of this type which could carry 20 amperes at 110 volts D. C. with an inductive load was considered a heavy duty switch, and its performance about the best that could be achieved in such a switch. With the present invention, however, the current carrying capacity of switches of this type has been at least tripled without shortening the life of the switch.

One problem involved in the operation of a high load mercury switch arises from the fact that mercury has both unfavorably high resistivity or specific resistance and unfavorably low specific heat. On the one hand, the effectiveness of a given electric current to generate heat by internal resistance is more than 55 times as great in mercury as in copper and, on the other hand, such internally generated heat has a temperature-raising effect on mercury three times as great as on copper.

Another problem resides in the necessity first, of employing metal for a high pressure switch envelope and second, of using a metal displacement member in the envelope to serve as an armature for electromagnetic actuation of the switch. Since one terminal of such a mercury switch is connected to the metal envelope and since the resistivity of the armature is lower than the resistivity of the mercury, current in the switch circuit tends to flow through the displacement member to or from the envelope. This tendency may be readily understood when it is considered that the resistivity of iron is approximately one eighth the resistivity of mercury.

The tendency for current to flow between the metal envelope and the enclosed armature increases with the switch current and is highly accentuated if the armature is in close proximity to the wall of the envelope. It is desirable to place the material of the armature close to the envelope wall both for the purpose of keeping the armature spaced away from the central arcing zone of the switch and for the purpose of causing the armature to be guided in its operative movement by the surrounding envelope wall.

In the type of displacement mercury switch in which the present invention has special utility, a cylindrical armature is surrounded by a cylindrical metal wall of the envelope and the armature is usually provided with peripheral guiding portions or radial spacer projections for cooperation with the surrounding wall. The coacting

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metal surfaces are smooth for minimum friction, the interior of the envelope being polished. Light current flow between the envelope wall and the ferromagnetic sleeve may have no seriously undesirable effect but any substantial current, say 20 amperes or more, will tend to melt the two metals and in a relatively short period of service result in such roughened and pitted coacting surfaces as to seriously interfere with freedom of movement of the armature. Sustained current flow substantially above 20 amperes may, in a conventional switch construction, actually weld the armature and envelope together.

A feature of my invention is the concept that the two problems of avoiding excessive mercury temperature and of avoiding serious deterioration of the coacting surfaces may be solved by the single expedient of properly extending a conductor of low resistivity and high current capacity from the metal envelope to the make-and-break zone of the switch. This expedient efficiently accomplishes its purpose, first, because it shortens the path of current flow through mercury and, second, because it affords a path of current from the envelope to the make-and-break zone of so much higher conductance than any possible path through the armature that no significant or damaging amount of current can flow between the envelope and the armature.

It is to be noted that shortening of what may be termed the "mercury path" by employment of the low resistance conductor enters into the solution of both problems since shortening the distance of current flow through the mercury both reduces the heating action of the current on the mercury and favors current flow through the conductor rather than through the armature. In my preferred construction, the conductance differential in favor of the conductor is increased by making the conductor relatively large in cross section and may be further increased by fabricating the conductor from material having substantially lower resistivity than the material of the armature.

One of the special objects in the preferred practice of my invention relates to the construction and mounting of a nonmetallic cup to hold a pool of mercury around one of the switch electrodes. In certain prior art practices, the ceramic material of a cup wall is fused or otherwise bonded to some other material either for the purpose of building up the cup itself or the purpose of mounting the cup on a suitable support. It has been found that any necessity for such bonding limits the choice of cup materials. If

fusing is employed, the most desirable ceramics may be precluded by the necessity of matching the interjoined materials with respect to their coefficients of thermal expansion. It has also been found that any necessity to employ a bonding agent involves certain difficulties since many bonding substances deteriorate in the presence of mercury, often with the resultant production of undesirable impurities.

The problem of mounting a nonmetallic cup on an electrode or other support is especially troublesome in those prior art arrangements in which some mounting means extends through and is bonded in an aperture in the bottom of the cup. Any deterioration of a bond in such location provides a short-circuit path of mercury through the cup aperture to make the switch inoperative or at least operative only in a faulty manner. With respect to the fabrication and mounting of a cup to contain a mercury pool, it is my object to provide a simple and effective mode of mounting a nonmetallic cup in the form of a unitary and imperforate body of material whereby bonding substances may be dispensed with entirely or only simple bonding substances or agents may be required. Since the cup body is imperforate, no bonding material is required to function as a mercury seal to prevent short circuiting and therefore any bonding substances or expedients employed need function merely as a mechanical connecting means with no consideration for leakage.

Other objects of my invention relate to methods and materials pertinent to the cost of manufacture and the ease of assembly of mercury switches. Some of these objects are to eliminate glass blowing thereby both to lower the cost of manufacture and to avoid excessive variation in the dimensions of fabricated parts; to provide for increased use of automatic machinery in the fabrication of mercury switches; to decrease the number and extent of testing operations required in the course of manufacture; and to achieve such uniformity in the switch parts as to simplify assembly and make possible the manufacture of substantially uniform subassemblies from randomly selected parts.

The above and other advantages of my invention will be apparent in the detailed description to follow taken with the accompanying drawing.

In the drawing, which is to be regarded as illustrative only:

Fig. 1 is a sectional view of a preferred form of my switch in one of its two operative positions;

Fig. 2 is a transverse section taken as indicated by the line 2—2 of Fig. 1;

Fig. 3 is a view similar to Fig. 1 showing the switch in its second operative position;

Fig. 4 is a sectional view of an alternative form of my invention; and,

Fig. 5 is a fragmentary sectional view illustrating a modification of the construction shown in Fig. 4.

The preferred embodiment of the invention shown in Figs. 1-3 includes a cylindrical switch envelope 10 enclosing a mercury fill 11 and a displacement means generally designated 12, the displacement means being in the form of an armature for electromagnetic switch actuation. In the normal or de-energized state of the switch, the displacement means 12 is free to float with its lower end partially submerged in the mercury fill as shown in Fig. 1. Energization of an exterior electromagnetic means generally designated 13 draws the displacement means 12 down-

ward to the position shown in Fig. 2 thereby raising the level of the mercury fill.

The electromagnetic means 13 may comprise a coil 15 having an iron circuit 16 and providing an axial opening to receive and retain the switch envelope 10. In the particular construction shown in the drawing, the iron circuit includes two circular pole pieces 17 defining an air gap 18 and the switch envelope 10 is mounted in proper position relative to the air gap by a rubber collar 19 tightly embracing an insulating sleeve 20. The insulating sleeve 20, which may be Bakelite, completely surrounds the switch envelope 10 and is suitably bonded thereto. Preferably a bracket 24 is adjustably mounted on the iron circuit 16 by a machine screw 29 to engage the rubber collar 19 as shown.

The switch envelope 10 comprises a cylindrical wall 21, an upper cap 22, and a lower cap 23. The cylindrical wall 21 is polished on its inner surface to minimize frictional resistance to movement of the displacement means 12 and is counterbored at its opposite ends to provide shoulders 25 and cylindrical flanges 26 to seat the two caps 22 and 23. The cylindrical wall 21 of the envelope should be made of metal that is nonmagnetic and also resistant to wetting by mercury. A suitable metal, for example, is a stainless steel known as "18-8 Steel" having besides iron, approximately 18% chromium and 8% nickel.

The upper cap 22 may be a metal disc or a pressed sheet metal member with an upturned flange 27 to nest inside of the cylindrical flange 26 against the shoulder 22. The joint between the cap 22 and the cylindrical wall 21 of the envelope may be sealed in any suitable manner, for example, by welding as indicated at 28. The cap 22 has a central flanged aperture 30 to embrace a body of insulating material 31 having the function of holding a switch electrode 32. The electrode 32 extends into the interior of the switch envelope 10 and at its outer end is adapted for connection with a wire 33 of the circuit to be controlled by the switch.

It is requisite that the materials of the cap 22, the insulating body 31 and the electrode 32 all have substantially the same coefficient of thermal expansion to maintain effective sealing relationships under varying temperature conditions. In my preferred embodiment of the invention, the electrode 32 is made of molybdenum, the insulating body 31 is a hard glass such as Corning G705AJ fused both to the electrode and to the cap, and the cap 22 is fabricated from a metal known to the trade as "Kovar," an alloy manufactured by Stupakoff Laboratories, Pittsburgh, Pennsylvania.

The second wire 35 of the circuit to be controlled by the switch may be soldered to the cap 22 as indicated in the drawing or may be attached to any other part of the switch envelope 10.

The lower cap 23 likewise is formed with a cylindrical flange 36 to nest against the shoulder 25 at the lower end of the cylindrical wall 21, the cap being sealed by welding 37. The cap 23, which may be machined from cold rolled steel, is formed preferably with an inner central boss 38 and has an axial bore 40 sealed by a headed pin or plug 41. In the course of manufacture, air may be evacuated from the welded envelope through the bore 40 and then a suitable inert gas or mixture of inert gases may be introduced through the same bore to fill the envelope under pressure. The gas or gases may be selected from

a group comprising hydrogen, nitrogen, argon, and helium hydride. After the gas has been introduced to the desired pressure, the head of the pin or plug 41 is welded to seal the bore 40.

Mounted on the lower cap 23 within the interior of the switch envelope is a conductor 42 which may be regarded as a second electrode since it cooperates with the first electrode 32 for switch action in a central make-and-break zone. In accord with the basic concept of my invention, the conductor 42 is designed to provide a path of relatively low resistance and relatively high current-carrying capacity from the switch envelope to the make-and-break zone. This purpose is accomplished by using conducting material of sufficiently low resistivity and sufficiently large in cross section. A chromium-plated copper conductor may be preferable because the resistivity of copper is substantially lower than the resistivity of the iron or steel of the displacement means 12. A chromium-plated iron or steel conductor of larger cross section would be equivalent. The conductor may be fabricated from "18-8 steel" since it is desirable that the conductor be nonmagnetic and resist wetting by mercury. Cold rolled steel is also satisfactory.

The conductor or electrode 42 may be mounted on the lower cap 23 in any suitable manner or may be fabricated in one piece with the cap. In the depicted construction, the conductor is a round rod machined to provide a circular flange 43 at its lower end to snugly and rigidly embrace the cap boss 38. A press fit may be relied upon to unite the conductor with the cap or the conductor may be welded to the cap as indicated at 45. The lower end of the conductor 42 has a short axial bore 46 and a diametrical bore 47 for communication with the previously mentioned axial bore 40 of the cap to complete the passage for evacuating the envelope and charging the envelope with inert gas.

In the preferred embodiment of the invention shown in Fig. 1, the conductor or electrode 42 supports a cup 48 for retaining a pool of mercury 50 immersing the end of the upper electrode 32. While the cup may be constructed in any suitable manner and may be mounted in any suitable manner, a feature of the present form of my invention is the concept of employing an imperforate cup body in mechanical engagement with the conductor 42, instead of employing a cup body that has an aperture for mounting the cup requiring a sealing agent to prevent the formation of a short-circuiting mercury path through its aperture. Thus, as shown in the drawing, the cup 48 may be a one-piece ceramic body having a stem or projection 51 fitting snugly and rigidly into a socket or recess 52 in the upper end of the conductor 42. To prevent retraction of the cup stem, I may insert a cotter pin or rivet 53 diametrically through the cup stem and through the surrounding wall of the socket.

If desired, a bonding substance may be employed instead of the cotter pin. For example, the stem of the cup may be dipped in molten glass before being inserted into the electrode socket, the molten glass cooling to form a strong mechanical bond. As so employed, the bonding substance need not perform the function of a seal and may, in fact, be quite inefficient as a liquid seal. It is apparent that by virtue of the described construction, I am free to employ any desirable ceramic material for the cup without regard to the coefficient of thermal expansion of

the ceramic material, the fusibility of the material, or the fineness of its grain structure.

The displacement means or armature 12 may comprise a cylinder 55 of suitable ferromagnetic material such as iron and may be formed with radial projections or be otherwise designed for guiding cooperation with the surrounding switch envelope. In the present construction, for example, the cylinder 55 is formed with integral radial flanges 56 at its top and bottom, each of the flanges being cut away as shown in Fig. 2 to provide guiding lugs 57 and intervening mercury-flow passages 58.

Preferably, I employ coil springs 60 of non-magnetic material at the opposite ends of the ferromagnetic cylinder 55 to serve as buffer means. If either of the caps 22 and 23 is of ferromagnetic material, such coil springs are especially desirable to prevent the displacement means from clinging to the cap magnetically. The term "displacement means" is to be understood either as applying to the ferromagnetic cylinder 55 alone or as covering the cylinder together with its coil springs 60.

In some practices of my invention, such as the practices illustrated in the present disclosure, I place a wall of insulating material such as glass or some suitable ceramic between the displacement means 55 and the cup 48 for the purpose of lengthening the minimum possible path of mercury from the displacement means to the pool 50 in the cup. Any current flowing between the displacement means and the cup must pass around the ends of such an insulating wall. Obviously the insulating wall may be fixedly mounted in the switch envelope in any suitable manner or may be carried by the ferromagnetic cylinder 55. In my present construction, the insulating wall is in the form of a cylinder or tube 61 mounted inside the ferromagnetic cylinder in the manner of a liner. Preferably the insulating cylinder 61 extends beyond the lower end of the ferromagnetic cylinder 55 but terminates short of the unrestrained extent of the lower coil spring 60.

The employment of an insulating wall such as the cylinder 61 is highly desirable because it enables me to design the mercury switch compactly, especially in cross section. It is to be understood, however, that the insulating wall may be omitted in some practices of my invention since the conductance differential required to confine current flow substantially to the conductor or electrode 42 may be achieved by increasing the diameter of both switch envelope and the displacement means to provide relatively great radial spacing between the cup 48 and the surrounding material of the ferromagnetic cylinder 55.

In the preferred practice of my invention another expedient employed to prevent current flow between the switch envelope and the displacement means is the coating of the displacement means with a suitable high resistance material selected from materials that will not react with the mercury. For example, I may coat at least the peripheral surface of the displacement means with magnetic oxide of iron Fe_3O_4 as stated in my Patent 2,121,804 issued June 28, 1938. When such a coating is formed on the displacement means, the resistance of the displacement means multiplies to discourage current flow there-through.

The operation of the described switch may be readily understood from the foregoing description. In Fig. 1, the coil 15 is de-energized, dis-

placement means 12 is at its upper position by virtue of its bouyancy with respect to the mercury fill, and the mercury fill is at its minimum liquid level 62 substantially below the rim of the cup 48. No current can flow through the switch because the major mercury body is separated from the mercury pool 50. No short circuit through the cup is possible because the cup is of unitary imperforate construction. Energization of the electromagnet draws the displacement means 12 to its lower position shown in Fig. 3 thereby displacing the mercury to the maximum liquid level 63, the maximum liquid level being above the rim of the cup 48 to cause the major mercury body to merge with the pool 50 to form a conducting bridge between the upper electrode 32 and the lower electrode 42.

It is to be noted that in the closed position of the switch shown in Fig. 3, current flow between the two electrodes passes through mercury for only a short distance since the conductor 42 extends upwardly close to the bottom of the mercury cup, and extends laterally substantially to a vertical plane at the side of the cup. On the other hand, any current flowing between the displacement means 12 and the upper electrode 32 must pass under the lower edge of the insulating cylinder 61 to traverse an excessive distance through the mercury. Since the resistivity of the mercury is so much greater than the resistivity of any of the structural metals, the disparity in length of the available mercury paths may alone account for the required favorable conductance differential. The conductance differential is, however, augmented by making the conductor 42 relatively massive.

The second embodiment of my invention shown in Fig. 4 is largely similar to the first described form, as indicated by the use of corresponding numerals to designate corresponding parts. In this second form of the invention I employ a relatively extensive upper electrode 70 and mount a mercury cup 71 on the lower end of the electrode. Here again, the ceramic body of the cup is unitary and imperforate to avoid any possibility of a short circuit through the cup wall. For mounting the cup 71 on the electrode 70, I rely upon a mechanical relationship, for example, forming the lower end of the electrode with screw threads to engage complementary threads in an axial recess 72 in the bottom of the cup.

A lower conductor or electrode 76, shown in Fig. 4 does not have the function of supporting the cup 71, and therefore need not make actual contact with the cup. It does, however, have the function of creating the required conductance differential and therefore is relatively large in cross section and extends upward a sufficient distance to materially shorten the mercury path between the two electrodes. Preferably the lower conductor extends laterally, as shown, to substantially a vertical plane at the side of the cup so that current may flow in substantially a straight line from the lower electrode along the side of the cup to the mercury pool.

Instead of relying on a screw thread engagement between the upper electrode 70 and the cup 71 or like mechanical relationship, I may use a bonding substance. Thus, as indicated in Fig. 5, the screw threads may be omitted from both the electrode and the cup recess and an intervening layer 77 of glass or other suitable material may be relied upon to hold the cup rigidly on the lower end of the electrode.

Either the switch shown in Figs. 1-3 or the

switch shown in Fig. 4 may be designed as a front contact switch or a back contact switch, that is to say, may be normally open or normally closed when the electromagnet coil is de-energized. It will be noted that the specific form shown in Figs. 1-3 is a front contact switch while the specific form shown in Fig. 4 is a back contact switch.

Fig. 4 shows the displacement means 12 floating on the mercury fill with the liquid level of the fill sufficiently high to immerse the cup 71. Upon energization of the coil 15, the displacement means is lifted from its normal floating position sufficiently to cause the liquid level of the mercury fill to drop substantially below the lip of the cup 71 to open the circuit.

My description, in specific detail, of preferred forms of the mercury switch will suggest to those skilled in the art various changes and substitutions under my basic concept and I reserve the rights to all such departures from my description that properly lie within the scope of my appended claims.

I claim:

1. In a mercury switch, a metal switch envelope for connection with one side of a circuit, a mercury fill in the envelope, a metal displacement means of hollow configuration in said envelope, means to shift said displacement means thereby to vary the liquid level of the mercury fill, an electrode for the other side of the circuit having a portion exposed for mercury contact between the minimum and maximum levels of the mercury fill, and a conductor of lower specific resistance than mercury extending from the wall of said envelope to a point sufficiently near said exposed portion of said electrode to provide a mercury path to the exposed portion substantially shorter than mercury paths to said exposed portion from any points on said displacement means whereby said conductor cooperates with the mercury fill to provide a path from said envelope to said exposed portion of substantially greater conductance than any path through said displacement means and thereby prevents damaging current flow between the envelope and the displacement means under relatively high switch loading.

2. In a mercury switch, a metal switch envelope for connection with one side of a circuit, a mercury fill, a metal displacement means of hollow configuration in said envelope, said displacement means being shaped and dimensioned for guidance by the envelope, means to shift said displacement means thereby to vary the liquid level of the mercury fill, a cup fixedly supported within the interior of said displacement means to hold a pool of mercury between the minimum and maximum liquid levels of the mercury fill, an electrode for the other side of the circuit contacting said pool, and a conductor of lower specific resistance than mercury extending from the wall of said envelope to a point sufficiently near said cup to provide a mercury path to the interior of said cup substantially shorter than mercury paths to the interior of the cup from any points on said displacement means whereby said conductor cooperates with the mercury fill to provide a path from said envelope to said pool of substantially greater conductance than any path through said displacement means and thereby prevents damaging current flow between the envelope and the displacement means under relatively high amperage switch loading.

3. In a mercury switch, a metal switch envelope for connection with one side of a circuit, a mer-

cury fill, a metal displacement means of hollow configuration in said envelope, said displacement means being shaped and dimensioned for guidance by the envelope, means to shift said displacement means thereby to vary the liquid level of the mercury fill, a cup fixedly supported within the interior of said displacement means to hold a pool of mercury between the minimum and maximum liquid levels of the mercury fill, an electrode for the other side of the circuit contacting said pool, and a conductor of relatively large cross section of metal having substantially lower specific resistance than mercury and substantially lower specific resistance than the material of said displacement means, said conductor extending from the wall of said envelope to a point sufficiently near said cup to provide a mercury path to the interior of said cup substantially shorter than mercury paths to the interior of the cup from any points on said displacement means whereby said conductor cooperates with the mercury fill to provide a path from said envelope to said pool of substantially greater conductance than any path through said displacement means and thereby prevents damaging current flow between the envelope and the displacement means under relatively high amperage switch loading.

4. A mercury switch as set forth in claim 3 in which said conductor is formed with a passage for communication with the exterior of said envelope in the course of manufacture and in which means is provided to seal said passage.

5. In a mercury switch, a metal switch envelope for connection with one side of a circuit, a mercury fill, a metal displacement means movable in such envelope, means to shift said displacement means thereby to vary the liquid level of the mercury fill, a cup fixedly supported in said envelope to hold a pool of mercury above the minimum liquid level of said fill, an electrode for the other side of the circuit contacting said pool, a nonconducting wall between said displacement means and said cup to lengthen the path of conduction through the mercury fill from the displacement means to said pool, and a conductor of substantially less specific resistance than mercury connected with said envelope, said conductor extending toward said cup to lessen the path of conduction through the mercury from the envelope to the pool whereby the conductance from the envelope to the pool through said conductor is substantially greater than the conductance from the envelope to the pool through said displacement, the conductance differential being sufficient to preclude damaging current flow between the envelope and the displacement means under relatively high amperage switch loading.

6. In a mercury switch, a metal switch envelope for connection with one side of a circuit, a mercury fill, a metal displacement means movable to vary the liquid level of said mercury fill, means to actuate said displacement means, metal buffer means yieldingly extending from the submerged end of said displacement means, a cup fixedly supported in said envelope to hold a pool of mercury between the minimum and maximum

liquid levels of the mercury fill, an electrode for the other side of the circuit contacting said pool, a wall of insulating material between said displacement means and said cup to lengthen the path of conduction through the mercury from the displacement means to said pool, said wall being carried by said displacement means and terminating short of the unrestrained extent of said buffer means, and a conductor of substantially less resistance than mercury extending from said envelope towards said cup to lessen the path of conductance from the envelope to the pool through the mercury whereby the conductance from the envelope to the pool through said conductor is sufficiently greater than the conductance from the envelope to the pool through said displacement means to preclude any damaging current flow between the envelope and the displacement means under relatively high amperage switch loading.

7. In a mercury switch, a metal switch envelope for connection with one side of a circuit, a mercury fill, a metal displacement means of hollow configuration within said envelope having peripheral portions for guiding cooperation with the envelope, means to shift said displacement means thereby to vary the level of the mercury fill, a cup to hold a pool of mercury above the minimum liquid level of the fill, an electrode for the other side of the circuit contacting said pool, and a support means rigidly carried by the envelope for supporting said cup, said support means being of material of substantially lower specific resistance than mercury and extending to a point providing a mercury path to the interior of said cup substantially shorter than mercury paths to the interior of the cup from any points on said displacement means whereby said support means cooperates with the mercury fill to provide a path from said envelope to said pool of substantially greater conductance than any path to said pool through the displacement means and thereby prevents damaging current flow between the envelope and the displacement means under relatively high amperage switch loading.

8. In a mercury switch, a metal switch envelope for connection with one side of a circuit, a mercury fill, a metal displacement means movable in the envelope to vary the liquid level of the mercury fill, means to actuate said displacement means, a non-metallic cup to hold a pool of mercury between the minimum and maximum liquid levels of said fill, a first electrode for the other side of the circuit contacting said pool, and a second electrode extending from a wall of said envelope to said cup to support the cup, said second electrode in at least one transverse dimension extending substantially to the side of the cup thereby providing a mercury path from the second electrode along the side of the cup to said pool, substantially shorter than the shortest mercury path from the displacement means to the pool to prevent damaging current flow between the switch envelope and the displacement means at relatively high amperage switch loading.

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