Dec. 17, 1963 G. T. KOHMAN 3,114,811

REDUCTION OF STICKING OF MERCURY-WETTED CONTACTS

Filed Nov. 16, 1961

FIG. 1
(PRIOR ART)

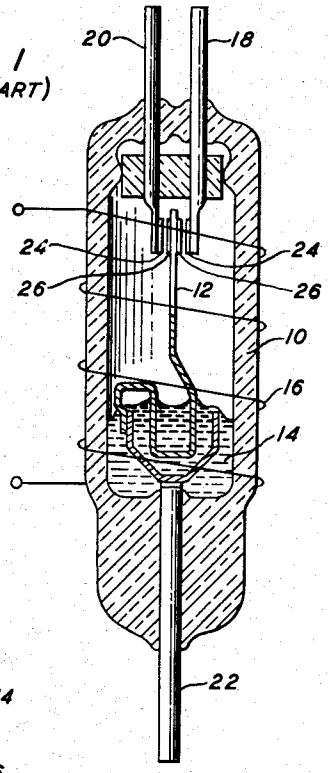


FIG. 2

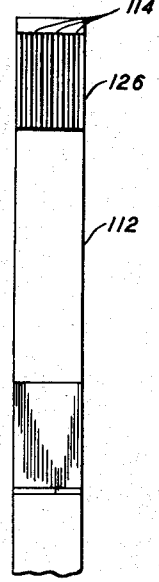


FIG. 4

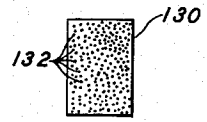
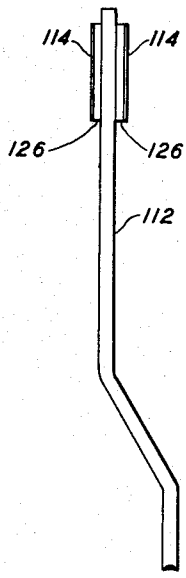


FIG. 3



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REDUCTION OF STICKING OF MERCURY-WETTED CONTACTS

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This invention relates to switches; more particularly it relates to switches which employ mercury-wetted contacts.

Appreciable difficulty has been encountered with switches of the prior art employing mercury-wetted contacts because the contacts tend to stick together preventing the opening of the circuit which the switch is designed to control.

In many instances the difficulty has appeared to arise because of the formation of amalgams of the contact metals with the liquid mercury, the amalgams adhering to each other and providing an electrical bridge across the contacts which is not destroyed by the normal operation of the switch intended to break the circuit by separating the contacts.

In accordance with one feature of the present invention, the above described difficulty is substantially eliminated by the provision of an array of inert members, hereinunder designated "spacers," on one of the contacting surfaces of each pair of contacts. The spacers are chemically inert insofar as any interaction with mercury is concerned. They are proportioned and arranged so that a film of liquid mercury covers the entire surface of the contact, preferably including also the surfaces of the spacers. Such contacts have appreciably less tendency to stick when normal operation to break the electrical connection, that is, to open the switch, is initiated. As will be described in detail hereinunder, the array of spacers can be a plurality of closely spaced linear elements or it can be a plurality of particles liberally distributed over the surface of the contact.

In accordance with a second feature of the present invention, the pairs of contacting surfaces comprise one surface essentially of iron with a very thin oxide layer thereon, and a second surface of a noble metal. In accordance with the teachings of the prior art, it has always been considered undesirable to permit the formation of an oxide film on either contact and both contacts have usually been made of a noble metal, such as gold, silver, ruthenium, rhodium, palladium, osmium, iridium or platinum.

As is well known to those skilled in the art, electrical conduction occurs through a single thin insulating film, such as a thin iron oxide film, provided its thickness does not exceed about ten angstroms. This is believed to result from a phenomenon known as "tunnel conduction" though no tunnels or pores of any sort can be shown to be present in the film. Furthermore, two such films placed immediately adjacent each other would be likely to present too high an electrical resistance. Therefore, by making one contact only of each contact pair of iron on which a very thin surface film of oxide is present and making the other contact of the pair of a noble metal which is readily wet by mercury, the single oxide film on the iron contact will not interfere with the flow of current but, in accordance with the teaching of the present invention, it will effectively prevent sticking of the contacts. Of the noble metals, platinum is preferred because of its low solubility in mercury. The higher solubility of gold and silver, for example, if these metals are employed for the other contact, could, under certain conditions, result in limiting the fault-free life of the switch in that it could cause sticking difficulties as a result of the formation of too large a quantity of amalgam. Furthermore, such contacts by a continuation of the formation of amalgam are likely to disintegrate.

In accordance with a third feature of the present invention, a novel surface treatment of contact carrying springs or armature members is proposed, which treatment facilitates wetting of the surface so treated with liquid mercury. The treatment results in providing a surface covered with finely divided particles of metallic nickel. Such a granular surface has been found to have a pronounced "wick" action with liquid mercury in that it is effective in drawing liquid mercury from a reservoir to wet contacts at the upper end of a vertical spring or armature member, the lower end of which extends into a liquid mercury reservoir.

A principal object of the invention is, accordingly, to substantially reduce the difficulties resulting from the sticking of mercury-wetted contacts in relays and similar switching devices.

Another object is to provide pairs of contact surfaces for switching devices in which the contact surfaces are mercury-wetted which have a minimum tendency to stick.

A further object is to impart "wick action" to surfaces of metallic members employed in switching devices which have mercury-wetted contacts.

The above and further objects, features and advantages of the invention will become apparent during the course of the following detailed description of illustrative embodiments of the invention taken with the accompanying drawings in which:

FIG. 1 illustrates a typical prior art switching device employing mercury-wetted contacts;

FIG. 2 is a front view of a spring or armature member embodying certain principles of the invention and suitable for use in the device of FIG. 1;

FIG. 3 is a side view of the member of FIG. 2; and

FIG. 4 illustrates an alternative form of contact of the invention.

In more detail in FIG. 1, a typical mercury-wetted contact switching device is shown to an enlarged scale. Normally, for example, the over-all length of glass envelope **10** is made one inch and other parts of the assembly are of correspondingly reduced dimensions. This specific device is, with exceptions to be described in detail hereinbelow, similar to the switching devices disclosed, described in detail, and claimed in Patent No. 2,609,464, granted September 2, 1952, to J. T. L. Brown and C. E. Pollard, Jr., and Patent No. 2,868,926, granted January 13, 1959, to C. E. Pollard, Jr., both of which patents are assigned to applicant's assignee. Accordingly, Patents 2,609,464 and 2,868,926 are incorporated by reference and, insofar as they are pertinent, are made an integral portion of the disclosure of the present application.

The principal parts of the device of FIG. 1 are a glass envelope **10**, enclosing a mercury reservoir **14** at its lower end, a contact bearing armature **12** held on a metal pedestal member **22** embedded in the lower end of envelope **10**, a pair of contact bearing metal stud members **18** and **12**, likewise embedded in envelope **10** but at its upper end, and a solenoidal electrical winding **16** encircling the central portion of envelope **10**. Envelope **10** is sealed and may be substantially evacuated or it may be filled with a chemically inert gas in accordance with practices well known and widely used in the art.

In one mode of operation, for example, a direct current passed through winding **16** in one direction (or polarity) will cause the upper end of armature **12** to move to the right bringing its right contact **26** into contact with contact **24** on the lower end of stud **18**. A direct current of the opposite direction (or polarity) through winding **16** will cause the upper end of armature **12**

to move to the left, closing the armature's left contact **26** with contact **24** on the lower end of stud **20**. Contacts **24** and **26**, in accordance with prior art practice, were usually both of a noble metal selected from the group mentioned hereinabove. Magnetic flux path structures, similar to that shown in the Brown-Pollard patent, enabling winding **16** to effect the above described operations are well known in the art and are omitted in FIG. 1 to avoid unnecessary complication of the drawing since the present invention is directed to the solution of problems involving essentially the contact members only.

In accordance with a first feature of the present invention, contacts **26** on opposite sides of armature **12** are preferably of iron (or an iron alloy) having a very thin oxide coating thereon. This oxide coating should be, for example, approximately ten Angstroms or less in thickness. The above contrasts with the prior art teaching that each of the contact surfaces should be of a noble metal and should not be permitted to become oxidized. Contacts **24** on supports **18** and **20**, respectively, are of a noble metal, and more particularly, a metal such as platinum which is readily wet by mercury but with a minimum of amalgam formation. It is common practice to alloy a small amount of nickel (ten or twelve percent by weight) with the platinum which further facilitates wetting its surface with mercury. As the glass envelope **10** is normally sealed so as to be gas-tight, it is entirely feasible and often the practice to seal it off with an inert or nonoxidizing gas, such as nitrogen, filling it so that further oxidation of the contacts will not occur after envelope **10** is sealed. Contacts **26** may, of course, be introduced into envelope **10** with an appropriately thin oxide coating. Alternatively, the thickness of the oxide coating on the iron may be reduced after it is assembled in the glass envelope by treatment in a reducing atmosphere such as hydrogen prior to filling the envelope with an inert atmosphere and sealing it. Such a thinly oxidized iron contact paired with one of platinum will freely pass electrical current but will form negligible coatings of amalgam with mercury so that the problem of the contacts sticking is substantially eliminated.

In accordance with a second feature of the invention, where an element of a switch, such as armature **12** of FIG. 1, is required to draw liquid mercury from a reservoir to the contacts in order that the contact surfaces shall be mercury-wetted, the surface of the member from a point below the surface of liquid mercury in the reservoir up to the upper end of the contacts is plated with metallic nickel. Alternatively, the member may be fabricated from a nickel strip of appropriate size. The surface is then wetted with mercury and allowed to form a layer of amalgam (of mercury and nickel, obviously). Such a surface will form a thin layer of amalgam at room temperature in a few hours. However, in order to thicken the layer of porous nickel amalgam so as to increase the capillary action, it is preferable to subject the nickel to several temperature cycles between room temperature and an elevated temperature (100 degrees centigrade or higher), maintaining the higher temperature for an hour or more during each cycle. After this treatment the nickel surface when wet with mercury will have a granular, bright "tinny" appearance. Upon heating again, but in a vacuum, the excess mercury can be distilled from the surface exposing a grey film of amalgam crystals. Upon further heating for a few minutes, for example fifteen minutes, at about 300 degrees centigrade (or at a lower temperature for a proportionately longer period) the amalgam crystals can be decomposed, the mercury being distilled off, leaving behind a black granular deposit consisting of a finely divided layer of metallic nickel. This layer is porous and readily wet by mercury. Furthermore, a member with such a surface will exhibit a pronounced "wick" action, that is, if held in a vertical position with its lower end dipped in liquid mercury, capillary action readily draws mercury to the upper end of the member.

In accordance with a third feature of the invention, the surface of one contact of each pair of mercury-wetted contacts is provided with an array of thin, closely spaced members, which are chemically inert to mercury. In one form these members may be parallel, elongated bar-like members, as illustrated to a further enlarged scale in FIGS. 2 and 3 by members **114**, extending vertically across the surface of contacts **126** on armature **112**. Armature **112** may be otherwise identical with armature **12** of FIG. 1 and may be substituted for the latter in the assembly of FIG. 1. Contacts **126** are, for example, as mentioned above, preferably platinum.

Preferably, spacers **114** of FIGS. 2 and 3 can be obtained by spraying a thin layer (approximately .001 inch) of a ceramic glaze or glassy material on the surface of a contact **126**, after which the bars **114** are formed by the mechanical removal (as by milling) of those parts of the film not required to form the bars **114**. Each bar can, for example, be approximately a mil (.001 inch) wide and the spacing between bars **114** can be of similar width. The thickness of the film should be somewhat less than the thickness of the mercury film between spacers which normally will be of substantially a mil, but since glass or ceramic glaze if meticulously cleaned will be wetted by mercury, it can be somewhat thicker in some cases.

If a film of an inert material which is not readily wetted by mercury, such, for example, as unglazed ceramic or numerous oxides, or metals such as iron, chromium and titanium, is employed, then the thickness of bars **114** should be restricted to not more than the thickness of the mercury film between spacers (one mil) and the intervals between bars should be several mils so that the mercury wetting of the contact surface between spacers will provide a layer of liquid mercury of equal or greater maximum thickness than that of the bars.

Alternatively, as illustrated in FIG. 4, an array of randomly distribued, closely spaced granular particles **132** may be affixed to the surface of the contact member **130** in lieu of the bars **114** of FIGS. 2 and 3. These can, for example, be of clean silica or of a semiconductor such as silicon carbide and may be embedded in the contact surface during fabrication when the surface is in a partially molten state or by powder metallurgy techniques. The surface upon solidification can then be etched to expose portions of the particles to a depth in the order of .001 inch.

Either the bars **114** of FIGS. 2 and 3 or the particles **132** of FIG. 4 will act as "spacers" so that contact is made through a film of liquid mercury. A contact provided with such spacing elements will have a negligible tendency to stick to a conventional contact of noble metal.

Numerous modifications and variations of the above described embodiments of the principles of the invention can readily be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In a switching device of the type which employs a pair of solid metallic mercury-wetted contacts for making and breaking an electrical circuit, one of said contacts having an array of a plurality of thin spacing members of a chemically inert and electrically nonconductive substance on its surface.

2. In a switching device, a pair of solid metallic mercury-wetted contacts for making and breaking an electrical circuit, one of said contacts comprising a member of iron having a thin layer of oxide thereon, the other contact comprising a member of a noble metal.

3. In a switching device, a pair of solid metallic mer-

cury-wetted contacts for making and breaking an electrical circuit, one of said contacts including thin spacing members of a chemically inert and electrically nonconductive substance on its surface, the spacing members being adapted to hold a fluid mercury film on the contact surface.

4. In a switching device of the type which employs a reservoir of mercury and a pair of solid metallic mercury-wetted contacts for making and breaking an electrical circuit, at least one of said contacts being supported on a first end of a movable supporting member, the other end of the member being in contact with the mercury in the reservoir of mercury, the surface of the supporting member between the mercury in the reservoir and the contact surface being covered with a granular layer of finely divided metallic nickel.

5. In a switching device, a pair of solid metallic mercury-wetted contacts for making and breaking an electrical circuit, one of said contacts containing a granular, chemically inert material incorporated in the surface of the contact, portions of the grains of said material protruding above the surface of the contact for a distance of approximately .001 inch.

6. In a switching device, a pair of solid metallic mercury-wetted contacts for making and breaking an electrical circuit, one of the contacts containing elongated

spacers arranged in parallel array, the spacers being of a material chemically inert with respect to mercury and electrically nonconductive.

7. In a switching device, a pair of solid metallic mercury-wetted contacts for making and breaking an electrical circuit, one of said contacts containing chemically inert and electrically nonconductive spacers distributed over its surface in a manner permitting the contact surface to be readily wetted by a fluid film of mercury of sufficient thickness to make contact with the other contact.

8. In a switching device, a pair of solid metallic mercury-wetted contacts for making or breaking an electrical circuit, one of said contacts containing a discontinuous thin layer of a vitreous enamel or glaze as a spacer arranged to permit the formation by surface tension forces of a fluid film of mercury over the contact surface.

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