

Dec. 2, 1969

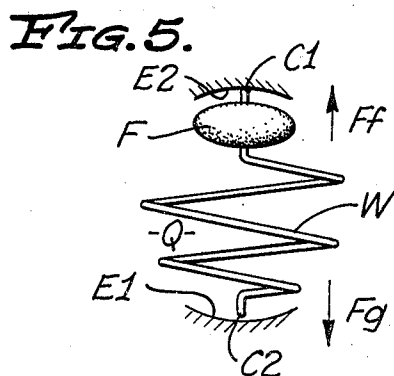
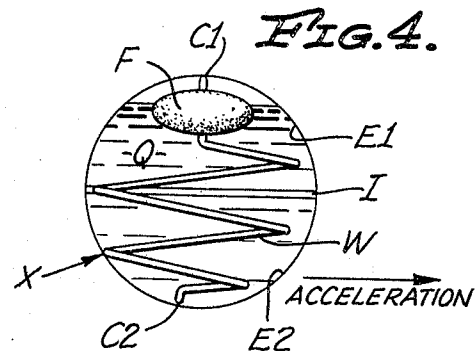
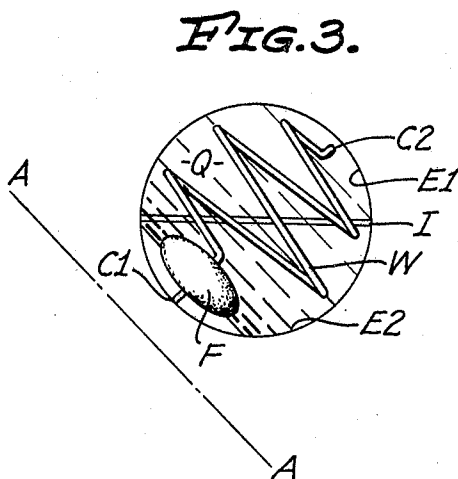
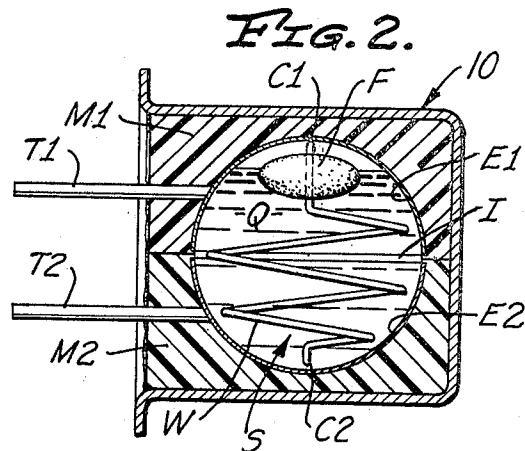
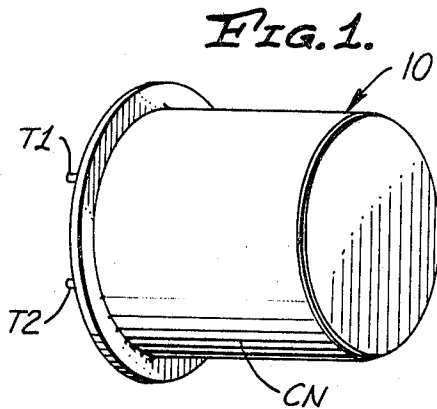
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3,482,066

ACCELERATION RESPONSIVE SWITCH INCLUDING A BUOYANT SENSOR

Filed Dec. 30, 1968

2 Sheets-Sheet 1



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ACCELERATION RESPONSIVE SWITCH INCLUDING A BUOYANT SENSOR

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2 Sheets-Sheet 2

FIG. 6.

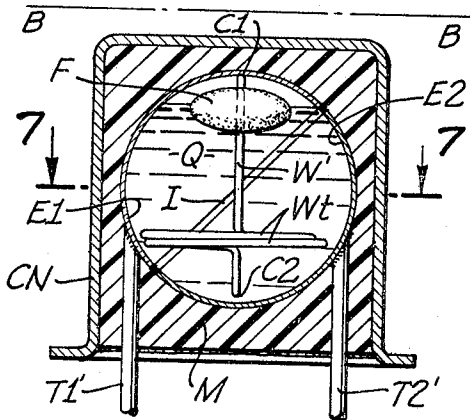


FIG. 7.

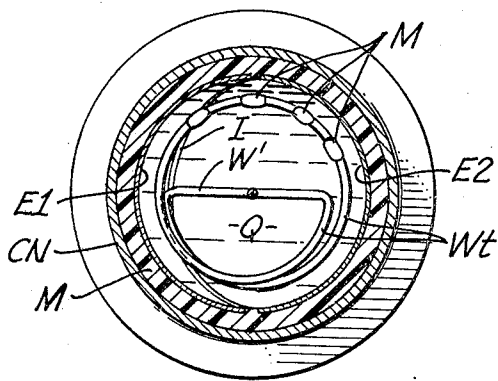


FIG. 8.

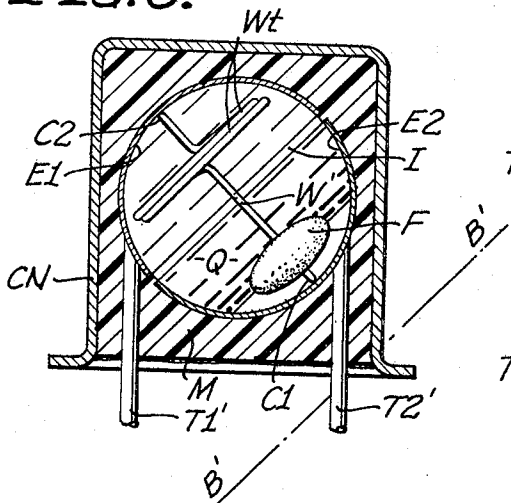


FIG. 9.

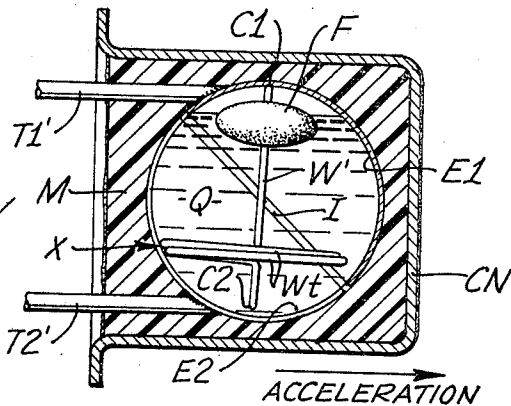


FIG. 10.

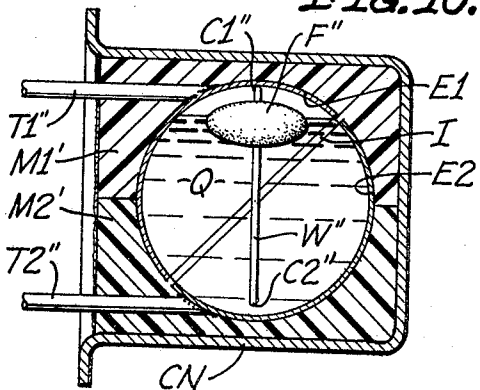
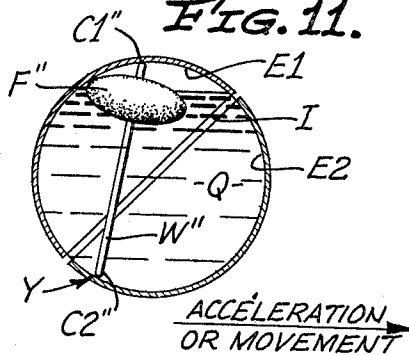


FIG. 11.



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ACCELERATION RESPONSIVE SWITCH INCLUDING A BUOYANT SENSOR

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U.S. Cl. 200—61.45

8 Claims

ABSTRACT OF THE DISCLOSURE

A miniature sensitive electrical switch adapted to close a circuit between terminals incident to very slight movement in any direction or when the switch is rotated about an axis outside the switch. A spherical chamber having mutually insulated substantially hemispherical conductive walls is occupied by a fluid in which a float and contact members are buoyed so that one contact member is in contact with one conductive wall and the other is slightly removed from the other wall until the switch is moved or rotated about an external axis.

BACKGROUND OF THE INVENTION

Sensitive electrical switches are of numerous types. However, none is presently capable of maintaining open-circuit status, irrespective of spatial attitude, while at rest; and capable of closing a circuit irrespective of spatial attitude, in response to very slight movement or rotation about an axis external to the switch. A switch having those capabilities and characteristics is of great value in alarm systems, fusing mechanisms, and other fields. The present invention attains the noted capabilities by virtue of a unique combination of electrodes or terminals of unique shape with circuit-closing contact members buoyed in a fluid in a manner such that one contact member is maintained in electrical contact with one or the other of the electrodes because of the nature of the buoyancy while the other member is thereby maintained out of contact with, but in close proximity to, the other of the electrodes or terminals unless the switch is moved in any direction or rotated about an axis outside the switch. In either of the latter situations, and irrespective of the initial spatial attitude of the switch, a circuit between its first and second terminals is momentarily closed.

SUMMARY OF THE INVENTION

In accord with the present invention means are provided which present in opposed face-to-face relation two substantially hemispherical conductive surfaces or electrodes which are mutually insulated by a narrow intervening zone of insulation, the means being so constructed or sealed as to form a closed spherical chamber. The otherwise unoccupied space in the chamber is occupied by a non-conductive fluid such as a fluorocarbon liquid; and a buoyant device is immersed in the fluid, the device comprising flotation means and first and second electrically-interconnected contact members, associated with and carried by, the flotation means. The immersed buoyant device is so devised that one contact member is, by virtue of the buoyancy of the flotation means, pressed against the wall of the chamber, and the other, or second contact member, substantially opposite the first member, is held close to but spaced from the wall unless the switch is subjected to acceleration in some direction. Thus the first contact member is urged against one of the two hemispherical electrodes and the oppositely-directed second contact member is maintained close to, but spaced from, the second electrode, at all times during which the switch is not subjected to acceleration other than that of gravity. The electrodes are disposed in a housing or support by means

of which they are held in the noted juxtaposition and whereby the switch may be mounted. When the previously quiescent switch is subjected to linear acceleration the first contact member, which is preferably closely adjacent to the flotation means, remains in contact with the wall of the spherical chamber at a first of the hemispherical electrodes and thereby makes one electrical contact of the two that are necessary to complete the circuit. At the same time the second contact member is moved relative to the switch housing and electrodes, and dependent upon the direction of the acceleration, into contact with the wall of the spherical chamber and into contact with the second of the two hemispherical electrodes. Each of the two electrodes is electrically connected to a respective external terminal whereby the switch can be connected to an external electric circuit. Thus, irrespective of the spatial orientation of the switch assembly, the contacts remain in open-circuit condition until the assembly is subjected to movement. In one exemplary construction, circuit closure is momentary, while in another exemplary construction the circuit closure is maintained during the entire period of forced acceleration of the switch. These are inherent modes of operation, each dependent upon a respective contact configuration, and both the result of the fact that regardless of the spatial orientation of the switch assembly, the contact assembly will always orient in the direction of the vector of applied force.

DESCRIPTION OF THE DRAWINGS

An exemplary illustrative embodiment of physical means incorporating the principles of the invention, and exemplary modifications, are depicted in the accompanying drawings forming a part of this specification and in which drawings:

FIGURE 1 is a pictorial view of an exemplary complete encased switch according to the invention, to a grossly enlarged scale;

FIGURE 2 is a longitudinal sectional view of the switch depicted in FIGURE 1, with one exemplary form of contact device;

FIGURE 3 is a diagram depicting the attitudes of switch components of the embodiment illustrated in FIGURE 2 when the switch is rapidly rotated about an axis of rotation external to the switch, the axis shown having been chosen arbitrarily;

FIGURE 4 is a diagram illustrating the action of the switch components of the form depicted in FIGURE 2, incident to the switch being subjected to acceleration in an arbitrarily selected direction;

FIGURE 5 is a diagram illustrating forces acting upon the exemplary movable components of the switch shown in FIGURE 2, when the switch is at rest relative to the earth or a similar near body of very large mass;

FIGURE 6 is a partial sectional view of a switch as depicted in FIGURE 1, but having a different form of resilient contact device and a changed orientation of electrodes, according to the invention;

FIGURE 7 is a sectional view of the switch device shown in section in FIGURE 6, the section being taken as indicated by designators 7—7 in the latter drawing;

FIGURE 8 is a view similar to FIGURE 7, but depicting the changes effected in the disposition of the contact device incident to rapid rotation about an arbitrarily chosen axis external to the switch device;

FIGURE 9 is a view illustrating the switch device as in FIGURE 6, but spatially oriented in an arbitrarily selected attitude and subjected to acceleration in an arbitrarily selected direction;

FIGURE 10 is a view similar to FIGURE 2, but illustrating a switch having a simplified type of contact device according to the invention which is adapted to effect

only momentary circuit closure incident to movement or angular acceleration of the switch during the speed-up period; and

FIGURE 11 is a schematic diagram of the electrodes and contact device of the switch shown in partial section in FIGURE 10, illustrating the spatial attitude of the contact device when the switch is subjected to acceleration in an arbitrarily selected direction therein indicated.

DESCRIPTION OF THE PREFERRED EXEMPLARY EMBODIMENT

Referring first to FIGURES 1-5, the exemplary switch is denoted generally by the number 10. The components include first and second terminals T1 and T2 of wire, first and second substantially hemispherical electrodes E1 and E2, a thin or narrow insulator I serving to insulate the electrodes from each other, a mass or body of fluid Q which occupies the otherwise unoccupied space in the substantially spherical chamber S whose spherical wall is formed by the inner surfaces of the electrodes and insulator, and a contact device buoyant in fluid Q. In the form illustrated in FIGURES 1-5, the contact device comprises at least first and second contacts C1 and C2 and a flotation device F to which the contacts are mounted or connected. The electrodes E1 and E2 may be merely conductive coatings formed on hemispherical depressions in insulation members M1 and M2, or they may be metallic shells, in either case the structure presenting opposed hemispherical inner walls or surfaces. The shells, if used, are embedded in or adhesively secured to members M1 and M2. The terminals means T1 and T2, which are shown as pin terminals but which may obviously be flexible wire leads or connectors, electrically connect to, and are conductively secured to, respective ones of electrodes E1 and E2, as indicated in FIGURE 2.

The insulation members M1 and M2 are adhesively bonded or otherwise united with thin insulator I. Together with the contained components E1, E2, F, C1 and C2, members M1 and M2 are fitted into a housing or container CN (which may be a conventional component-can) and therein sealed or potted in place with the terminal wires or pins protruding as indicated. Thus the relatively fixed components comprising members M1 and M2 and the conductive walls or electrodes E1 and E2, together with the thin insulator I, provide a sealed spherical chamber the principal walls of which are opposed conductive hemispherical elements or electrodes which may be internally interconnected by a contact device. The spherical chamber encloses a contact device which is freely movable therein to a limited extent and which when under the influence of only the gravitational acceleration assumes an attitude in which it contacts only the uppermost one of the hemispherical electrodes, but which responds to substantially any other acceleration by change of attitude and by contacting both of the electrodes.

Because of the flotation device F, the contact device is buoyant in the fluid Q which fills the space in the spherical chamber that is not occupied by the contact device. The fluid is selected according to the mass and volumetric displacement of the contact device, and according to the viscosity required to obtain the degree of sensitivity selected or desired. Also the fluid must be selected in respect of vapor pressure such that the switch will operate satisfactorily within the temperature range within which the switch is intended to operate. Examples of acceptable fluids operable in ordinary temperatures, and characteristics thereof, are set out in the following tabulation:

TABLE

Fluid	Density	Viscosity (cs.)	Pour Point, ° F.	Boiling Point, ° F.	Vapor Press (mm. Hg)
FC-78-----	1.70	.44	-100	122	260
FC-77-----	1.78	.88	-150	207	4.2
FC-75-----	1.77	.82	-155	216	2.7
FC-43-----	1.88	2.6	-58	235	.5
FC-40-----	1.88	2.3	-56	311	-----

Generally, the fluid used will be characterized by specific gravity in excess of unity, especially if the conductive means of the contact device is of a noble metal. The listed fluorinated hydrocarbon fluids are designated herein by the commercial designations applied thereto by the manufacturer, 3M Company, St. Paul, Minn. Other fluids may be used, such as CCl₄, but perfluorinated hydrocarbons are generally preferable because of chemical inertness.

The previously-described exemplary contact device comprises in addition to the contacts proper (C1 and C2) and the flotation device F, conductor means electrically interconnecting the contacts and serving additional functions such as spacing the contact points the proper distance apart and responding to accelerations of the switch electrodes and the contained fluid to cause the contacts to engage respective ones of the electrodes. Thus in the embodiment of switch illustrated in section in FIGURE 2, the interconnecting conductor means is preferably (but not necessarily) integral with the contacts C1 and C2, and consists of a resilient wire W a portion of which is formed into an expanded coil to form a spring of the general configuration shown. The conductor means may be of resilient wire or ribbon, for example, of beryllium-copper alloy, of platinum alloy, or of other metal or other resilient material plated with a conductive inert metal such as gold. As indicated, the contact-and-conductor means is attached, at or closely adjacent one end thereof, to the flotation device F so that the near contact C1 is brought into physical and electrical contact with the wall of the spherical chamber by the flotation device as the latter responds to the vectorial sum of the forces acting on it. In the preferred construction shown, the conductor W extends through the flotation device, the latter having been formed around a portion of the wire. Thus, assuming the housing to be disposed horizontally as in FIGURES 1 and 2, and stationary relative to the earth, the flotation means or float F assumes the position and attitude depicted in FIGURE 2 under the influence of gravity, with near contact C1 engaging the uppermost area of the spherical wall, and with the longer and heavier portion of wire W depending downwardly but relatively unstretched, with contact C2 spaced slightly away from the chamber wall adjacent a point diametrically opposite contact C1. As indicated, the surface of the flotation means adjacent contact C1 is curved so that it will not at any time interfere with engagement of the wall by C1.

Preferably, but not necessarily, wire W is in this example so coiled that its convolutions in relaxed state when in the fluid Q closely approach but do not contact the wall of the chamber. Thus the wire or "spring" is adapted to insure circuit-closing contact with the electrode opposite that engaged by contact C1 if and when contact C2 is positioned on the insulator I (and vice versa), by a portion of one of the convolutions becoming a second contact, and the wire is thus adapted to make contact and effect circuit closure incident to even very slight lateral acceleration of the switch. When oriented as depicted in FIGURE 2, upward acceleration of the switch housing results in float F following the upper electrode E1, slight stretching or elastic elongation of the coil formed of the resilient wire W, due to the differential mass thereof, and engagement of contact C2 with lower electrode E2 thereby effecting circuit closure between terminals T1 and T2. This action of the contact device occurs, irrespective of the spatial orientation of the switch housing. When the parts are similarly disposed and at rest and the switch housing is accelerated laterally, as indicated in FIGURE 4, float F continues to force contact C1 into engagement with electrode E1, the wire W tends to remain at rest at the C1 position, and relative movement of the lower electrode E2 and wire W brings the wire into contact with the electrode, the contact being made either along one of the convolutions as at the region marked X in

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FIGURE 4, or at contact C2, or both. In FIGURE 4, the direction of the imposed acceleration is indicated by the legend. In a modified form hereinafter described, the conductor is relatively rigid and relatively straight, and is useful for effecting only momentary circuit closure in response to the impulse of continuous orbit about an axis outside of the device.

When the switch illustrated in FIGURE 2 is rotated or "orbited" relatively rapidly around an axis external to the switch structure, for example as depicted in diagrammatic form in FIGURE 3 about the axis A—A, the flotation means tends to move toward the axis of the orbit with the near contact C1 pointing toward the axis and the wire W drawn in the opposite direction by the centrifugal force acting thereon as a result of the centripetal acceleration. Clearly the spring means, spring constant, flotation means and liquid may be designed and selected so that when the rotational (angular) speed is constant and of a determinable value the contact device will retain contact C1 engaged with the chamber wall nearest the axis and leave the circuit between the electrodes open with contact C2 free of the chamber wall, and such that thereafter if the angular speed is increased the wire will deform by elongation of the coil-spring portion thereof and bring contact C2 into electrical contact with the electrode opposite that engaged by contact C1. In general, in applications of the switch in a rotary mode of operation about an axis such as A—A, the acceleration due to gravity will be relatively negligible in comparison with that due to rotation about the axis. However, as is evident, the spring means, spring constant, buoyancy of the contact device, density of the fluid or liquid, viscosity of fluid, and the relative disposition of electrodes and housing, etc., may be selected so the switch will be sensitive to particular selected accelerations, such as acceleration in a particular direction, or about a particular external orbital axis.

The switch in its preferred more universal form is sensitive to translational acceleration and to angular acceleration about an axis outside the switch body or housing as well. As indicated in the diagrammatic FIGURE 5, when the contact device is at rest with only gravitational force acting on the switch, the buoyancy is effective to provide an upward force F_f which is opposite the gravitational force F_g . In the illustrative case is the gravitational force effective on the entire contact device; it is generally replaced by a greater force when the switch is rotated about an external axis. As is further evident, the switch may be constructed to be highly sensitive to one type of acceleration and less sensitive to another; and the sensitivity may be varied by change of spring constant, dimension changes, change of viscosity of liquid, type and shape of spring wire and of flotation means, and damping means. The flotation means may be, in the case of a small switch of the order of one-eighth inch sphere diameter, a small bead or pellet of natural or synthetic resin, ceramic, impermeable foam of glass or the like, of density lower than that of the fluid Q in the spherical chamber. In larger sizes of switch the float may be a hollow member of glass, ceramic, resin or the like immune to attack and penetration by the fluid. Attachment of the conductive means to the float may be by direct fusion thereto, by means of adhesive, or by other means; but in very small switches of the stated dimensions direct embedment of the wire in the bead or flotation member, as indicated in the drawings, is preferred.

In FIGURES 6, 7, 8 and 9 there is illustrated a switch of slightly modified form, in which the hemispherical electrodes E1 and E2 are spatially oriented with their insulative equatorial juncture disposed diagonally relative to the housing axis and relative to the planes defining housing ends or top and bottom. Further, therein the conductor W' interconnecting the first and second contacts C1 and C2 is formed to have its principal elastic portion

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composed of turns Wt disposed generally in or closely adjacent a plane perpendicular to the line connecting the two contacts. The spring thus provided may be of a variety of forms having many or few turns, that illustrated being exemplary and typical. Preferably the spring or resilient device formed by the coil or turns is made to be balanced with respect to the axis defined by a line passing through the contacts C1 and C2. Such balancing is effected by any of several means or techniques, such as using wire of varying cross-section, or of varying density, or, as illustrated in FIGURE 7, by application of balancing masses M to appropriate portions of the wire W'. Such balancing masses may be small deposits of metal-containing inert synthetic resin or adhesive, or masses of applied alloy such as solder, and their number, distribution and composition are selected and adjusted in accord with specifications as required.

The switch structure depicted in FIGURES 6-9 and comprising the electrodes E1 and E2, the inter-electrode insulator I, buoyed device W'-F-C1-C2, fluid Q, and terminals T1'-T2', is completed by encapsulating those components in housing can CN by compound M in the selected spatial attitude, preferably but not necessarily as depicted. In FIGURE 6, the relative positions of the components are as they would be under the influence of gravity alone, and as they would be if orbiting at a sub-critical or "non-switching" rate about an external axis B—B. In the orbiting mode, orbital rotation at a rate in excess of the predetermined critical value results in the resilient coil or turns Wt extending slightly and bringing contact C2 into circuit-closing contact with electrode E2.

In FIGURE 8, the relative attitudes of the switch device components are indicated when the device is orbited at a rate above the critical rate, about an external axis B'—B'. When rotated at or above a design-determined rate (for example, a rate at which the centrifugal force F_c is 20 times the local gravitational force) the wire and flotation structure orients itself with the near contact C1 directed toward the orbital axis and in contact with one electrode (E2 as shown) the wire coil or turns portion stretches or elongates slightly under the influence of the centrifugal force, and distant contact C2 contacts the other electrode (E1 as shown in this example). Prior to, or subsequent to, orbital movement at the critical rate, distant contact C2 is out of contact with an electrode, and the switch is in open-circuit attitude.

In FIGURE 9, the switch device of FIGURES 6-9 is depicted in a horizontal attitude and with the contact device shown in an attitude assumed as a consequence of short-term acceleration or disturbance of the switch device in a selected direction as indicated. As there indicated acceleration is toward the right, and as a consequence the lower portions of wire W' of the contact device tend by inertia to remain in position while the near contact C1 is maintained in contact with the chamber wall and electrode E1, whereby electrode E2 moves into one or more of the turns Wt of the contact device and circuit-closure is accomplished. The point of contact is designated at point X in FIGURE 9. Since the turns Wt can be so formed that the periphery thereof is very closely adjacent the interior surface or wall defining the fluid-filled chamber during quiescence of the switch device, it is evident that the switch may be designed to be very sensitive to very small linear accelerations or movements. When the switch device is spatially oriented as indicated in FIGURE 9, vertical acceleration upward of the device has the effect of stressing spring turns Wt and bringing contact C2 into electrical contact with electrode E2 by virtue of the movement of that electrode relative to contact C2.

In FIGURE 10, the exemplary switch according to the invention is depicted as comprising a contact device especially adapted to make only momentary electric-circuit closure incident to being disturbed or rotationally accelerated to a spinning speed. Following the circuit clo-

sure during disturbing movement or attainment of constant rotational velocity, the contact device moves to circuit-opening attitude. In the construction depicted in the noted drawing the housing CN may be substantially the same as previously described, containing hemispherical electrodes E1 and E2, insulator I, fluid Q, potting sealant such as M1'-M2', and terminals T1'-T2'. The contact device comprises essentially the flotation member F'' and a simple wire W'' whose ends provide contacts C1'' and C2''. The wire is preferably substantially straight or with only a minor bend in the longer portion, and is of length such that when disposed along a diameter of the fluid-filled chamber, contacts C1'' and C2'' do not close the circuit between the terminals, as is indicated in FIGURE 10. The change in relative positions of the electrodes and contacts when the device of FIGURE 10 is disturbed is, for one example of disturbance, indicated in the diagram of FIGURE 11. Therein, because of movement of fluid Q and electrodes E1 and E2 as indicated, contact C1'' is pressed against electrode E1 by flotation member F'' while electrode E2 and contact C2 have been brought into engagement at point Y. Promptly following this spatial disposition of the contact device, contact C2'' is adapted to move out of engagement with electrode E2, to open the circuit between the terminals. Thus the more elementary form of contact device, obviously less expensive to produce and install, may be employed in those situations wherein because of the provision of relay means or for other reasons only momentary circuit-closure is required or desired.

Various methods known in the physical-instruments art may be employed to fill the spherical chamber with the required fluid. For example, a pair of very small bores extending to the interior from the exterior of the switch may be used for exit of exhaust and entry of fluid, the bores being then plugged or sealed.

I claim:

1. An electric switch having first and second terminal means, comprising, with said terminal means:

first means, including means forming a closed substantially spherical chamber, said chamber being defined by means presenting first and second substantially hemispherical conductive inner walls mutually insulated each from the other by a narrow zone of insulation comprised in said first means, each of said conductive inner walls being in electrical communication with a respective one of said terminal means;

second means, including an electrically non-conductive fluid filling the otherwise unoccupied space in said spherical chamber;

and third means, including a device movable and buoyant in said fluid in said spherical chamber and said device comprising conductive means including electrically-interconnected first and second spaced-apart contact members and flotation means for rendering said device buoyant, said third means being so arranged that when said switch device is subjected to only gravitational force said flotation means tends to rise in said fluid and tends to urge said first contact member into contact with the uppermost of said hemispherical conductive walls and brings said second contact member to a position closely adjacent to but out of contact with the lowermost of said conductive walls;

whereby, incident to acceleration in a direction different from said gravitational force, said flotation means maintains said first contact member in contact with the spherical wall of said chamber and contacting one of said conductive walls and the other of said conductive walls comes into contact with said second contact member, to close a circuit which includes said first and second terminal means.

2. An electric switch according to claim 1, in which said flotation means is of smaller volume than either hemisphere of said chamber, and in which said conductive means includes a conductive resilient coil interposed between said flotation means and said second contact member, at least one convolution of said coil being closely adjacent the wall of said chamber but spaced therefrom when said switch is not being accelerated;

whereby upon said acceleration of said switch, said spaced-apart portions of said conductive means are brought into contact with respective ones of the said conductive inner walls.

3. An electric switch according to claim 1, in which said first means forming a closed substantially spherical chamber comprises first and second hemispherical shell-like members presenting opposed substantially hemispherical conductive inner walls and an electrical insulative member interposed between said first and second members as said narrow zone of insulation.

4. An electric switch according to claim 1, in which switch said fluid is a liquid and said first and second spaced-apart contact members are respective first and second end portions of a continuous conductive wire-like member a major portion of which extends away from one face of said flotation means.

5. An electric switch according to claim 4, in which said major portion of said wire-like member includes a multiple-turn coil.

6. An electric switch according to claim 1, in which said fluid is a liquid of specific gravity in excess of 1.

7. An electric switch according to claim 1, in which said first and second spaced-apart contact members are disposed at respective points along a diameter of said spherical chamber when said switch is not enduring acceleration.

8. An electric switch device according to claim 6, in which said flotation means is an insulative member of ellipsoid-of-revolution configuration and said conductive means is a substantially straight wire-like conductor one end portion of which is embedded in said insulative member with a short tip protruding to form said first contact member and a long lower portion extending away from said flotation means and providing at its end said second contact member.

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