

Feb. 2, 1943.

H. C. HARRISON

2,309,953

ELECTRIC SWITCH

Filed June 15, 1940

4 Sheets-Sheet 1

FIG. 1

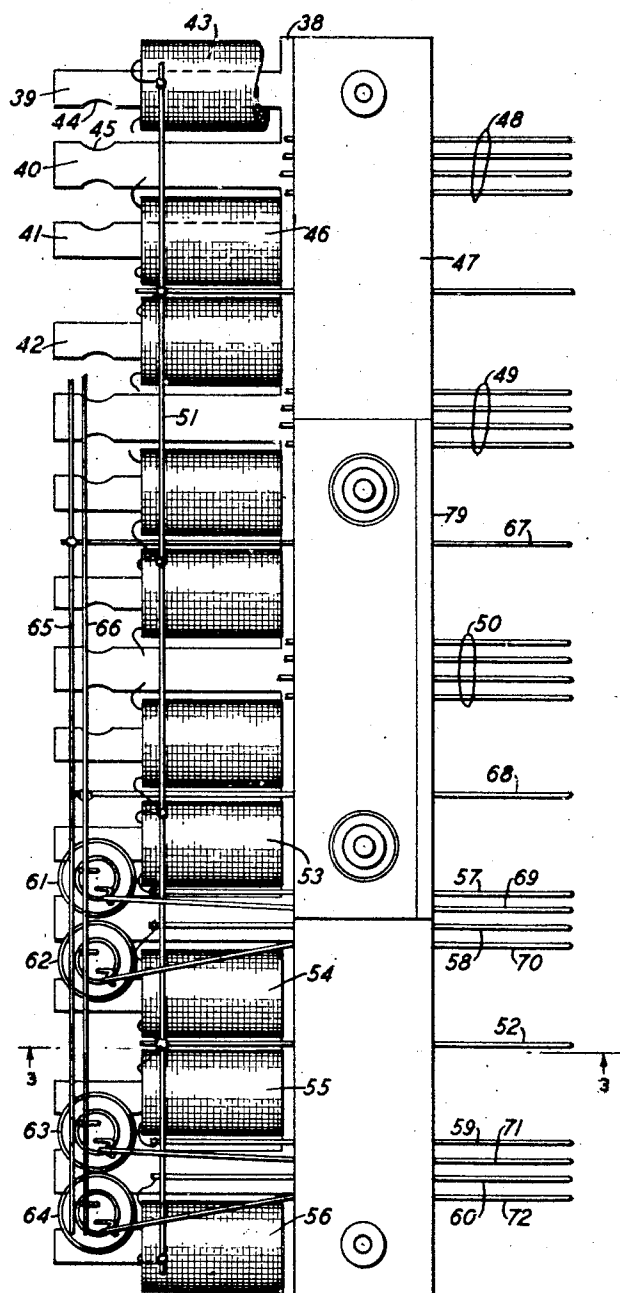
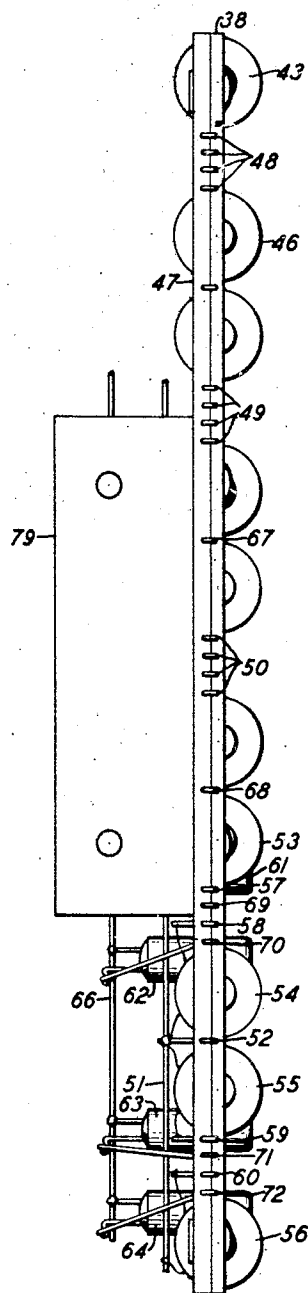


FIG. 2



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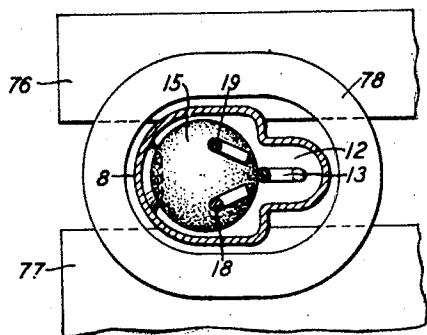
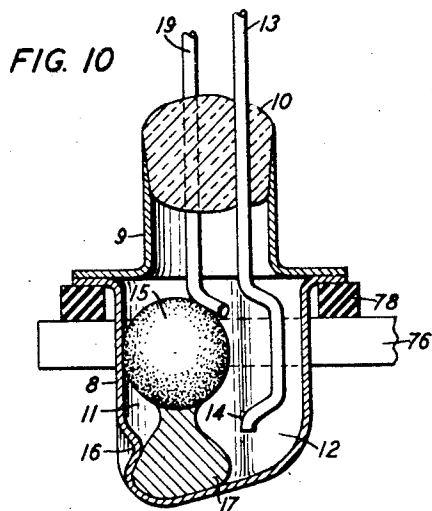
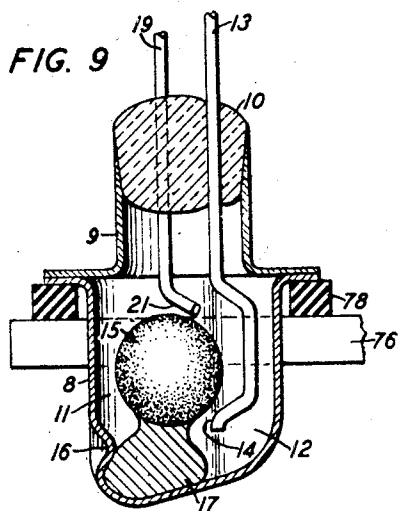
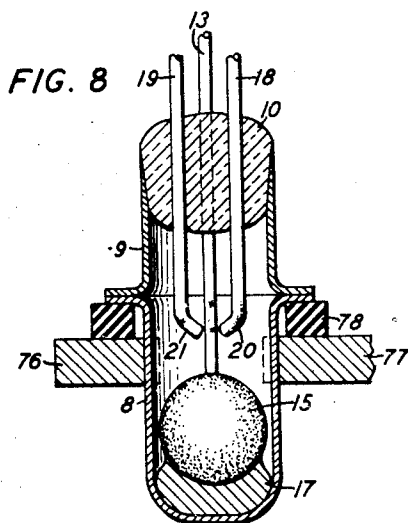
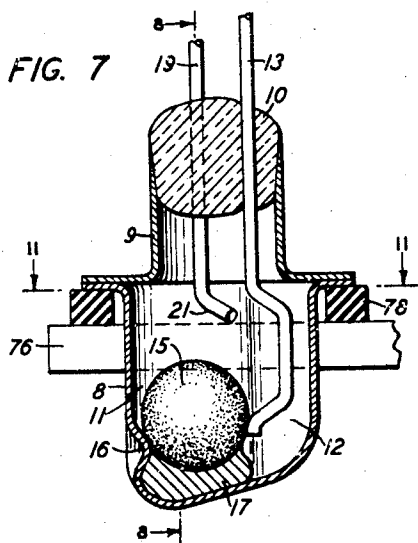
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ELECTRIC SWITCH

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4 Sheets-Sheet 2



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ELECTRIC SWITCH

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4 Sheets-Sheet 3

FIG. 3

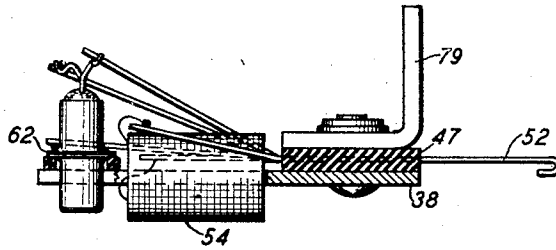


FIG. 4

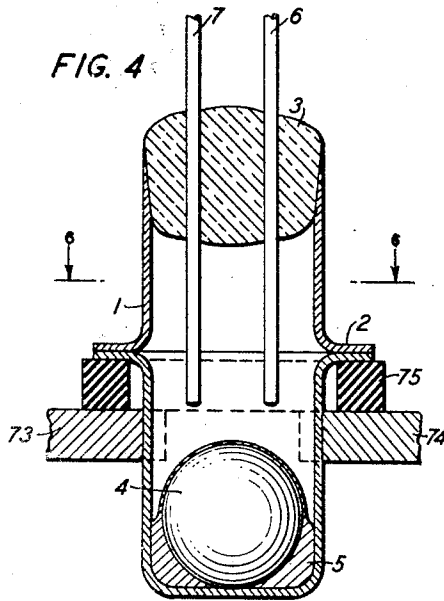


FIG. 5

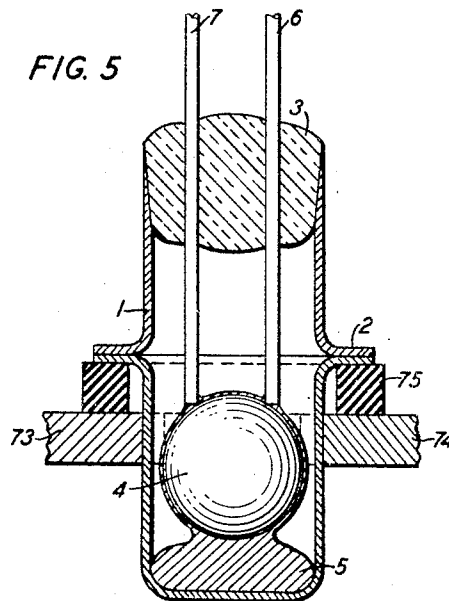
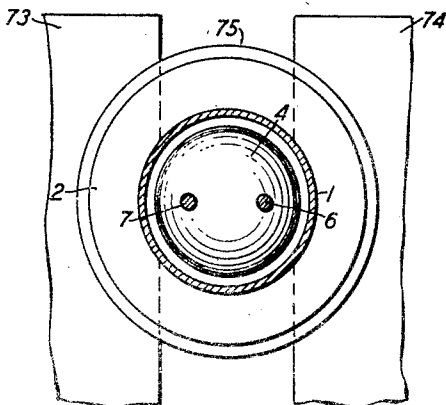


FIG. 6



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4 Sheets-Sheet 4

FIG. 12

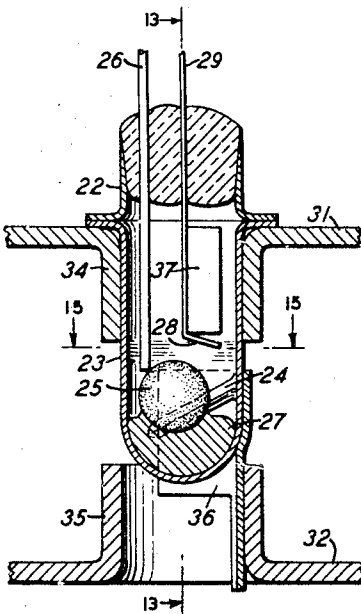


FIG. 13

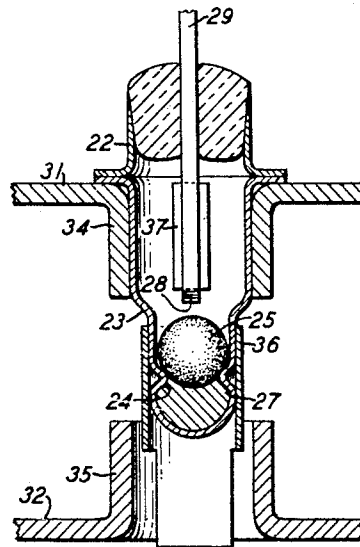


FIG. 14

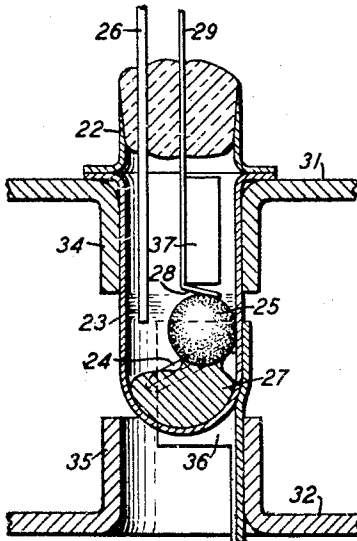


FIG. 15

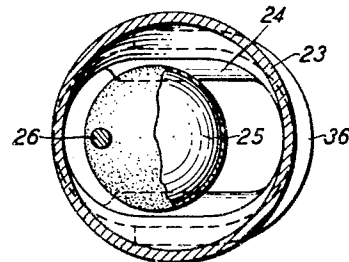
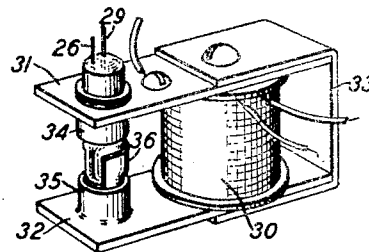


FIG. 16



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UNITED STATES PATENT OFFICE

2,309,953

ELECTRIC SWITCH

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Application June 15, 1940, Serial No. 340,653

7 Claims. (Cl. 200—112)

This invention relates to electromagnetic relays and switches.

The objects are to attain a greater degree of simplicity both in the structure and in the principle of operation of these devices; to realize a higher efficiency as a result of these simplifications; to improve the circuit-making contacts; to obtain improved magnetic circuits for operating these contacts; and in other respects to improve relays and switches for circuit controlling purposes.

It is well recognized that mercury has certain advantages over solid contacts for opening and closing electric circuits. Being a fluid, it presents a fresh surface for each contact closure and does not become corroded and pitted as a result of successive circuit interruptions. On the other hand solid contacts have advantages too. They can be made of materials that are lighter than mercury and can be moved at higher speeds. Also it is possible to apply the forces of the magnetic field more directly to solid contact-operating elements than to a mass of mercury for effecting the desired circuit closures and openings.

Accordingly the foregoing objects of the present invention are achieved by an improved switch or relay which realizes not only the advantages of mercury as a contact-making medium but also the characteristic advantages of solid contact elements.

To this end a feature of the invention is a switch comprising a housing tube or envelope having fixed terminals mounted therein and a movable armature in the form of a ball of magnetic material, together with a reservoir of mercury for maintaining at all times a covering of the liquid over the contact-making surfaces. More specifically the lower portion of the ball armature normally rests in engagement with the mercury pool, and the ball is of such dimensions that some of the mercury in the pool is attracted by capillary action over the entire surface of the ball. When the electromagnet is energized, the ball is pulled up from its normal resting position into engagement with the fixed solid terminals mounted in the upper part of the housing tube. Since the ball is constantly covered with a film of mercury, some of the liquid is deposited on the engagement surfaces of the fixed terminals each time the ball is attracted. Therefore the closing and opening of the circuit is reduced to the simple movement of a ball, which can be made to operate at relatively high speed, and each contact is made and broken by two cooperating surfaces of mercury.

Another feature of the invention is a switch of the character described in which the mercury in the pool not only creeps up over the surface of the ball by capillary action to supply a liquid

contact surface but adheres to the ball as the latter moves from its normal to its operated position. This adhesion of the mercury mass to the ball causes said mass to become displaced from its normal configuration in the pool, setting up forces of surface tension which tend to pull the ball back to its normal position. Hence when the magnetic attraction ceases, the pull of the mercury and the action of gravity restore the ball quickly.

A further feature is a switch in which the ball in its normal position engages one stationary terminal to maintain a circuit closure and in which the ball when attracted moves away from said terminal and into engagement with a second terminal, thus opening the first circuit and closing a second one.

The foregoing and other features of the invention will be described more fully in the following specification.

In the drawings accompanying the specification:

Fig. 1 is a top plan view of a relay assembly including a common operating magnetic structure and a plurality of individual relay operating means; Fig. 2 is a rear view of the assembly shown in Fig. 1; and Fig. 3 is a cross-sectional view of the assembly taken on line 3—3 of Fig. 1;

Figs. 4 to 15, inclusive, show a number of forms of the relay operating unit;

Figs. 4 and 5 are side views, partly in section, showing one form of the relay unit. The first of these figures shows the relay in its normal condition, and the second figure shows the relay when operated; and Fig. 6 is an enlarged cross-sectional view taken on the line 6—6 of Fig. 4 and also illustrating the relation of the relay unit to the magnetic operating structure;

Figs. 7, 8, 9 and 10 are side views partly in section showing a second form of the relay unit. In these views Figs. 7 and 8 illustrate the relay in its normal condition, Fig. 9 shows the relay partially operated, Fig. 10 shows the relay when fully operated, and Fig. 11 is a sectional view taken on the line 11—11 of Fig. 7, illustrating the position of the relay in the magnetic assembly;

Figs. 12, 13 and 14 are side views partly in section showing a third form of the operating unit. In these views Figs. 12 and 13 illustrate the normal condition of the relay, Fig. 14 shows the relay when operated, and Fig. 15 is a cross-sectional view taken along the line 15—15 of Fig. 12; and

Fig. 16 is an assembly view of a magnetic structure suitable for use with the relay unit shown in Figs. 12 to 15.

While the invention is not limited to any particular size or proportions for the relay operating unit it may be noted that this relay is especially

useful in electrical systems where relatively small currents are involved such, for example, as currents of the magnitude commonly used in telephone, telegraph and other communication systems. For these purposes the dimensions of the relay may be relatively small, and it should be understood that the figures shown in the drawings are much enlarged in order to facilitate a clear understanding of the construction.

Before discussing the relay assembly as a whole, which is illustrated in Figs. 1 to 3, a detailed description will be given of the relay operating units.

Referring first, therefore, to Figs. 4, 5 and 6, the operating unit here disclosed comprises a metal container 1 which is formed by welding together the circumferential flanges of two small cylindrical eyelets. The metal of which the eyelets are made is preferably of a non-magnetic character. If desirable, however, the upper eyelet may be made of magnetic material, such as stainless steel. The external shoulder 2 formed by the juncture of the flanges in the welding operation serves, as will be explained more fully hereinafter, to locate and hold the unit in position in the assembly. The upper end of the container or tube 1 formed from the eyelets may be sealed with a mass 3 of any insulating material, such as glass. During the welding operation or at any other convenient time the interior of the tube 1 may be evacuated and, if desired, filled with any suitable gas.

The process by which the housing tube 1 is formed and the process of evacuating it and charging it with a desired gas or gases are the subject-matter of a copending application by H. C. Harrison and J. B. Little, Serial No. 340,655, filed June 15, 1940.

The armature of the relay consists of a ball 4 of magnetic material. The ball 4, which may be either hollow or solid, normally rests in a mercury pool 5 in the bottom of the tube 1. The depth of the mercury pool, and the diameter of the ball are of such dimensions and the external surface of the ball is such that the mercury adheres or clings to the ball with considerable force and by capillary attraction constantly maintains a film of the liquid over the entire surface of the ball projecting above the level of the pool. These forces may be augmented by coating or plating the external surface of the ball 4 with certain substances, such as platinum, nickel, and copper, and by maintaining the coated surfaces free from corrosion. This may be done, as above mentioned, by introducing inert gases into the container.

The armature 4 cooperates with a pair of stationary terminals 6 and 7, which are sealed into the insulating mass 3. When it is desired to operate the relay, a magnetic field is produced for attracting the ball 4 upward into engagement with the contact surfaces of the terminals 6 and 7. As the ball 4 moves up out of the pool 5 to its operated position (Fig. 5), the adhesion of the mercury to the ball distorts the shape of the pool and sets up in the mercury mass forces of surface tension which tend to draw the ball back to its normal position.

Since the surface of the ball is constantly coated with a film of mercury, some of the liquid is transferred to the contact surfaces of the terminals 6 and 7 by the repeated engagement of the ball with these terminals. Thus each circuit closure between the terminals 6 and 7 by way of the mercury coated ball is in effect established by bringing two liquid covered surfaces together. Simi-

larly, each circuit opening is made by severing these liquid covered surfaces. In this way the solid contacts of the relay are protected against sparking, corrosion and the other detrimental effects.

When it is desired to release the relay, the magnetic field is removed, whereupon the force of gravity assisted by the forces of surface tension and adhesion in the mercury draws the ball quickly back to its normal position.

The relay shown in Figs. 7 to 11, inclusive, is designed to close one circuit in the normal position of the armature and a second circuit in the operated position. The container for this relay is formed by welding together two metal eyelets 8 and 9 and by sealing the open end of the upper eyelet 9 with a mass of insulating material 10. The lower eyelet 8 is shaped to provide a main chamber 11 therein and a recess or channel 12 communicating with the main chamber and formed by pinching in the side walls of the eyelet as seen more clearly in the cross-sectional view of Fig. 11.

The stationary terminal 13, which is secured in the seal 10, extends directly down to a point substantially opposite the upper end of the lower eyelet 8. At this point the terminal 13 turns into the recess 12 and extends downwardly therein for a substantial distance. Finally the lower end of the terminal 13 returns from the recess to a point in the main chamber where the tip or contact surface 14 of said terminal may be engaged by the ball armature 15. In its normal position (Fig. 7) the ball 15 is suspended by its engagement with the contact surface 14 of the terminal 13 and the reentrant portion 16 of the container. The pool of mercury 17 in which the ball 15 is partly immersed adheres to the ball and covers its entire surface with a thin film as previously described. The terminals 18 and 19, which are engaged by the ball 15 in its operated position, are also held in the seal 10. These terminals have their lower ends 20 and 21 bent at an angle, as seen in Figs. 7 and 8, to present the contact engagement surfaces and to form a guide for directing the ball into its operated position, as seen in Fig. 10.

When the relay shown in Fig. 7 is in its normal condition, a circuit path is closed from the metallic container, which serves as one of the relay terminals, through the mercury 17 and ball 15 to the terminal 13, the contact surface 14 of which is normally engaged by the ball. When it is desired to operate the relay, a magnetic field is produced, which acts to pull the ball toward the top of the container. As the ball engages the inclined surfaces 20 and 21 it is guided into the position shown in Fig. 10 where it encounters the side of the eyelet 8 and comes to rest. The mercury in the pool 17, adhering to the ball 15, is pulled into a distorted shape, as seen in Figs. 9 and 10, and the forces of surface tension produced by this displacement act to pull the ball back to its normal position. It will be noted that the width of the channel 12 is substantially less than the diameter of the ball 15. The edges of the channel, therefore, form a guide which prevents the ball from entering the recess 12 and engaging the terminal 13 therein, and directs the ball into engagement with the terminals 18 and 19. This construction insures that the ball 15, once it disengages the contact surface 14 of the terminal 13, will not reengage this terminal until it is fully restored to its normal position. When the ball 15 is in the operated position (Fig. 10), the normally-closed circuit path to the terminal 13 is

opened, and alternate circuit paths are established from the metal container through the mercury pool 17 and ball 15 to the stationary terminals 18 and 19. Upon removal of the magnetic field the ball 15 is withdrawn quickly to its normal position where it reengages the stationary terminal 13. The contact surfaces 14, 20 and 21 of the stationary terminals are covered with a film of mercury which is transferred thereto from the pool by the ball 15.

The relay disclosed in Figs. 12 to 15, like those previously described, also includes a metallic container made by welding together the upper and lower eyelets 22 and 23. The opposite sides of the eyelet 23 are constricted or pinched in to form an inclined interior track 24 for guiding the movement of the armature 25 between its normal and operated positions. In the normal position of the relay the ball 25 rests at the bottom of the inclined track against the stationary terminal 26, and also in engagement with the mercury pool 27, which fills the bottom of the container. In this position the ball 26 closes a circuit path from the metallic container through the mercury pool and ball to the terminal 26. When it is desired to operate the relay, a magnetic field is applied in such a way that the ball 25 is pulled upward and toward the right-hand side of the container, as viewed in Fig. 12. This attraction of the ball causes it to roll up the inclined track 24 until it engages the contact surface 28 of the stationary terminal 29. The reason for applying a lateral force to the ball 25 is to insure its disengagement from the stationary terminal 26 and to insure that it will engage only the terminal 29 when moved to its operated position, as seen in Fig. 14.

The magnetic structure (see Fig. 16) by which the operating force is applied to the armature 25 comprises an operating coil 30, pole members 31 and 32 and a non-magnetic member 33 which serves to hold the other parts in place. The magnetic members 31 and 32 are punched to present hollow cylindrical pole-pieces 34 and 35 respectively, which also serve as a container and holder for the relay unit. A supplemental magnetic member 36 is inserted in the pole-piece 35 and partly encircles the eyelet 23 on the sides remote from the stationary terminal 26. A second supplemental magnetic member 37 is secured to the stationary terminal 29 within the container. These supplemental magnetic members 36 and 37 cooperate with the pole-pieces 34 and 35 to produce a supplemental air-gap on the right-hand side of the tube, as viewed in Figs. 12 and 14. Since this supplemental air-gap is considerably shorter than the main air-gap between the pole-pieces 34 and 35, the ball 25 is always attracted to the supplemental gap. Therefore, the main force acting on the ball is one that pulls it in the direction of the inclined guide 24 and thus away from the stationary terminal 26. In the operated position of the relay the closed circuit path may be traced from the metallic container through the mercury pool 27 and ball 25 to the stationary terminal 29. When the ball is in its uppermost or operated position the mercury pool is distorted to store up the force that serves to quickly release the ball as soon as the magnetic field is removed.

The different types of relays above described are particularly applicable to multi-unit assemblies in which a plurality of individual relays are associated with a common magnetic structure. One such relay assembly is illustrated in Figs. 1

to 3 comprising a common magnetic member, individual operating coils and relay units mounted on said member and a common terminal member. The magnetic member 38 is made from a flat sheet of magnetic material and is formed like a comb with a series of teeth 39, 40, 41, 42, etc., which constitute the magnetic circuits for the individual relays. The teeth of the magnetic member 38 are arranged in groups of three, each group constituting the magnetic circuit for a pair of relays. For example, the teeth 39 and 40, together with the common portion of the strip 38, form the magnetic circuit for a single relay, the operating winding 43 being located on the tooth 39. The inner adjacent edges of the teeth 39 and 40 are provided with circular notches 44 and 45 to receive and hold one of the relay operating units, such as the unit shown in Fig. 4. Similarly the teeth 40 and 41 form the magnetic circuit for the second relay of the pair, and the operating winding 46 for this relay is located on the outside tooth 41. In like manner the remaining teeth of the magnetic strip 38 are arranged in groups of three.

The terminal member, which supplies the electrical connections for the operating windings and relay units, comprises an insulating strip 47 having molded therein or otherwise secured thereto a series of groups of terminals 48, 49, 50, etc. The terminal strip 47 is secured to the magnetic member 38, and the individual terminal conductors are connected in any desired manner with the terminals of the operating windings and with the terminals of the relay units.

Although the drawings illustrate one specific method of wiring the coils and relay units, numerous other wiring plans may be used depending upon the functions to be performed by the relays. In the plan illustrated in the drawings one terminal of each of the energizing coils is connected to a common bus 51 which in turn is supplied by the feed terminal wire 52. The other terminal of each coil is connected to an individual wire in the associated terminal group. For example, each of the coils 53, 54, 55 and 56, and the same is true of the remaining coils, has one terminal connected to the common bus 51. The other terminals of coils 53, 54, 55 and 56 are connected respectively to the terminal wires 57, 58, 59 and 60. Each of the relay units, such as the units 61, 62, 63 and 64, has one of its terminals connected to the common bus wire 65 and another of its terminals connected to the common bus wire 66. These bus wires are supplied over terminal conductors 67 and 68, respectively. The third terminals of these relay units are connected respectively to the individual terminal conductors 69, 70, 71 and 72.

When the relay units are thus assembled with the magnetic structure, the magnetic ball armature of each unit is located in operative relation to the air-gap formed by the adjacent teeth of the magnetic comb which support the unit. This relation is clearly shown in Fig. 4 where the ball 4 is seen to rest in its normal position somewhat below the center of the air-gap formed by the adjacent teeth 73 and 74. An insulating washer 75 may be inserted between the magnetic teeth 73 and 74 and the shoulder 2 on the container 1 to fix the desired relation between the armature 4 and the air-gap.

In like manner the alternative relay structures shown in the other figures of the drawings may be incorporated in a relay assembly similar to the one shown in Figs. 1 to 3. For example, the

relay illustrated in Figs. 7 to 11 may be mounted between the magnetic teeth 76 and 77 of the magnetic structure, these teeth being notched to accommodate the contour of the relay unit. The insulating washer 78 serves to support the relay container and to fix the relation between the ball armature and the air-gap between the magnetic teeth.

These relay assemblies may be mounted on relay racks, switch frames, or in any other desired manner, the assembly shown in the drawings being secured to a suitable supporting plate 79.

Although the teeth of the magnetic member 38 in Fig. 1 are shown with notches for receiving the relay units, it will be understood that these teeth may have straight edges if desirable, the relay units being held in place by any other suitable means.

What is claimed is:

1. The combination in an electric switch of a housing member, a pool of mercury in said housing member, a ball of magnetic material normally resting with a portion of its surface in said pool, the forces of capillary action serving to attract mercury from said pool to cover the remaining surface of said ball with a coating of the liquid, a fixed solid terminal mounted in said housing member, and electromagnetic means for moving said mercury-coated ball into engagement with said fixed terminal to establish an electric circuit.

2. The combination in an electric switch of an enclosed housing member having a pool of mercury therein, a ball of magnetic material normally resting with a portion of its surface immersed in said pool, the forces of capillary action serving to attract mercury from the pool to maintain a film of the liquid over the exposed surface of said ball, a fixed solid terminal mounted in said housing member and engageable by said ball to establish an electrical connection, and electromagnetic means for moving said ball from its normal to an operated position, the mass of mercury in said pool adhering to the ball as it moves from its normal to its operated position and exerting a force that serves to restore the ball to its normal position.

3. The combination in an electric switch of a closed housing tube having a pool of mercury in the bottom thereof, a ball of magnetic material normally resting in engagement with said mercury pool and coated with a covering of mercury derived from said pool, a fixed terminal mounted in said housing tube, and electromagnetic means for attracting said ball from its normal position and into engagement with said fixed terminal, the engagement surface of said fixed terminal being constantly covered with mercury transferred by the ball from said pool, the covering of mercury on said ball and on said fixed terminal serving the purpose of effecting circuit closures and openings through the medium of the mercury.

4. In an electric switch, a housing tube having a reservoir of mercury in the bottom thereof, a magnetic ball normally resting in engagement with the mercury in said reservoir, electromagnetic means for moving said ball from its normal position to an operated position, said housing tube being shaped to form an internal guide channel for guiding said ball in its movement, and a stationary terminal mounted in said hous-

ing tube engageable by said ball to establish an electric circuit.

5. In an electric switch, a closed housing tube having a pool of mercury therein, a ball of magnetic material normally resting in engagement with said pool and having its surface covered with a film of the liquid derived from the pool, a stationary terminal mounted in said tube and engaged by said ball to establish an electrical connection when the ball is in its normal position, a second stationary terminal mounted in said tube, and electromagnetic means for moving said ball from its normal position to disengage said first terminal and into an operated position where it engages its second terminal to establish a second electrical connection, said housing tube shaped with a constriction therein to form an internal channel for guiding said ball in its movement.

6. The combination in an electric switch of a closed housing tube having a pool of mercury therein, a ball of magnetic material normally resting with a portion of its surface in said pool and covered with a film of the liquid derived from said pool by capillary attraction, electromagnetic means for moving said ball from its normal position to its operated position within said tube, said tube having a constricted portion forming an internal channel serving as a guide for the movement of said ball from its normal position to its operated position, a stationary terminal mounted in said tube with a portion thereof lying in the recess of said channel beyond the reach of said ball and with the contacting portion thereof projecting out of said recess and into engagement with said ball when the latter is in its normal position, and a second stationary terminal mounted in said tube and engaged by said ball when the latter moves to its operated position.

7. The combination in an electric switch for effecting circuit closures and openings of a lower housing member formed of sheet metal, an upper housing member similarly formed, said members having flanges which are welded together, a mass of sealing material closing said upper housing member, a pool of mercury freely resting in the bottom of the enclosed chamber formed by said housing members, first and second circuit-making terminal members extending through said mass of sealing material into said chamber, a ball of magnetic material normally resting in engagement with said pool of mercury and having its surface covered with a film of the liquid derived from the pool by the action of capillarity, said ball in its normal position engaging the end of said first terminal member to close an electrical circuit, and means for moving said ball from its normal position to disengage it from said first terminal member and into an operated position where it engages said second terminal member to close a second electrical circuit, said film of mercury serving to protect said ball and terminal members when electrical circuits between said ball and members are opened and closed, said lower housing member being shaped with a constriction therein to form an internal guide channel to prevent said ball from reengaging said first terminal member while moving between its normal and operated positions.

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