June 19, 1962 L. C. SHAPIRO 3,040,147

MERCURY RELAY

Filed Sept. 22, 1958 4 Sheets-Sheet 1

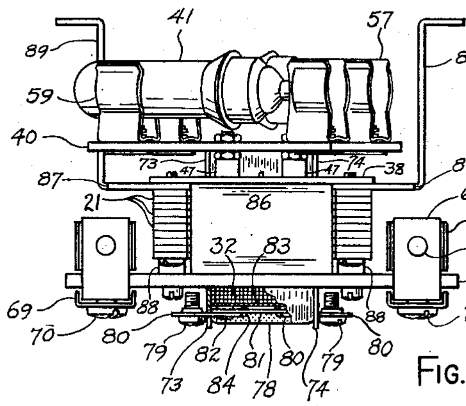

FIG. 3

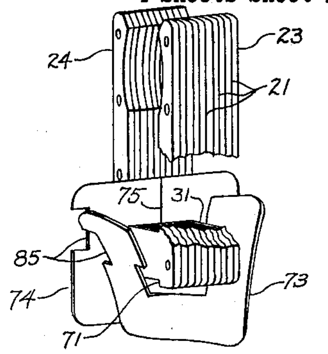

FIG. 4

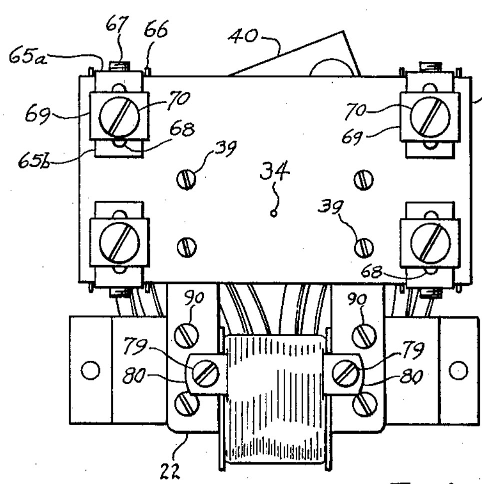

FIG. 1

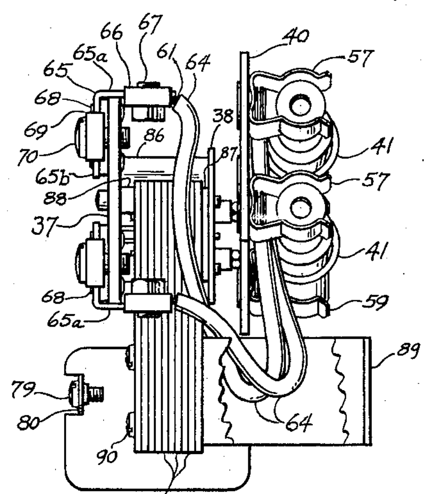

FIG. 2

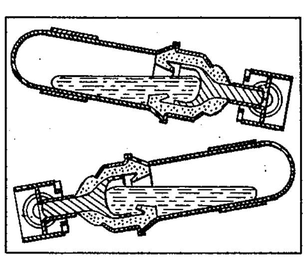

FIG. 16

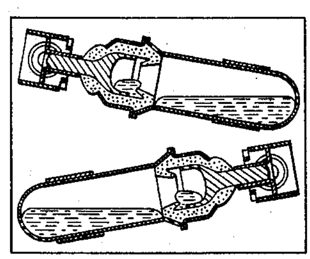

FIG. 17

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MERCURY RELAY

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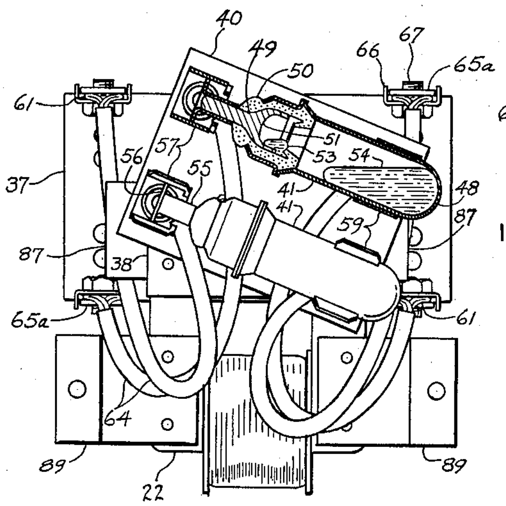

FIG. 5

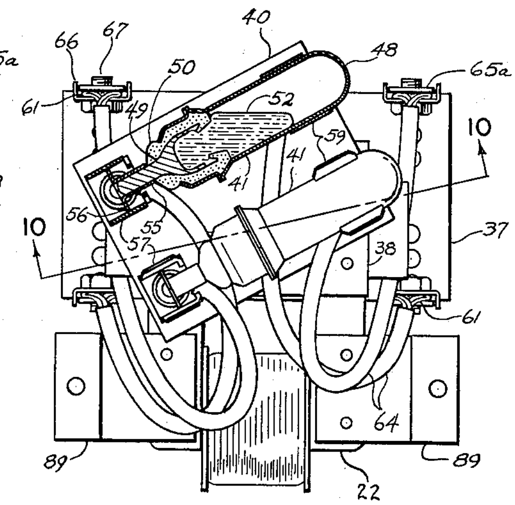

FIG. 6

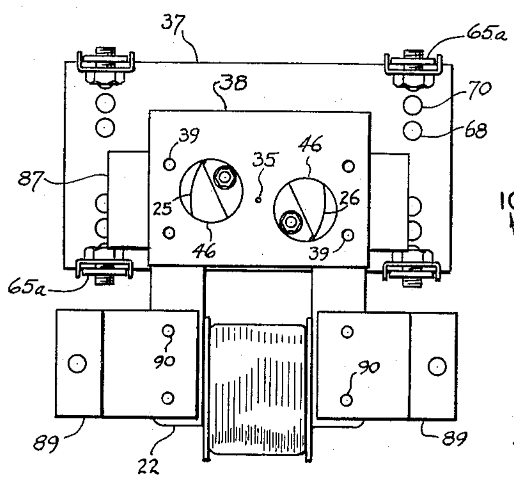

FIG. 7

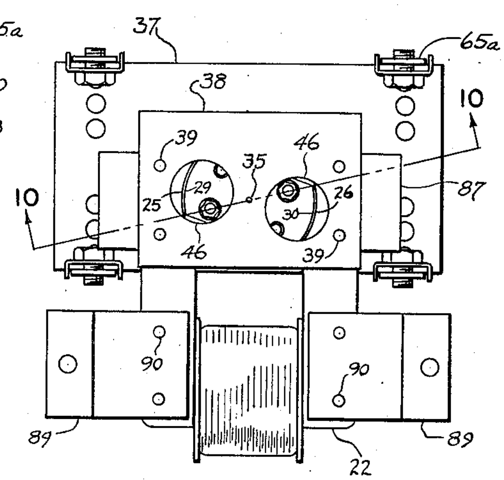

FIG. 8

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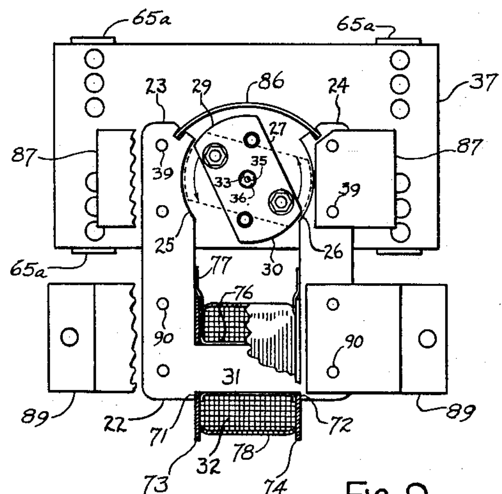

FIG. 9

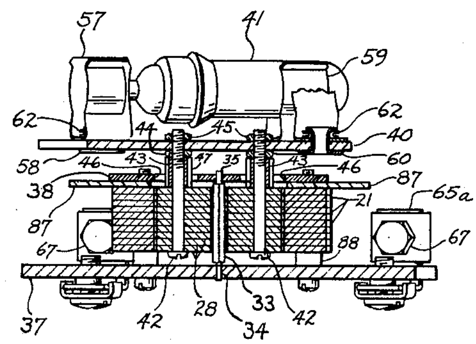

FIG. 10

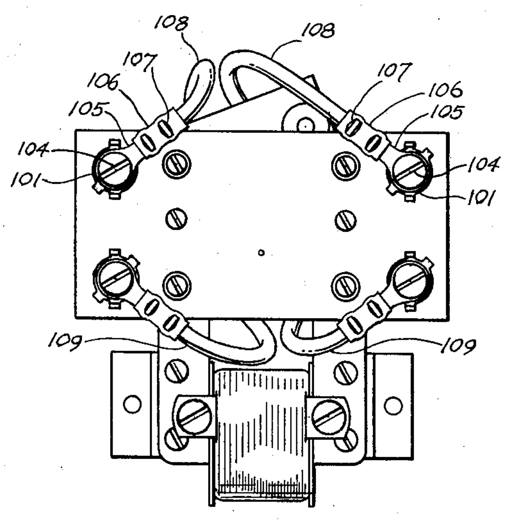

FIG. 11

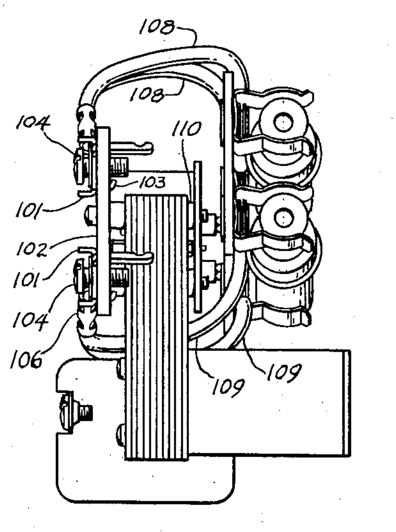

FIG. 12

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MERCURY RELAY

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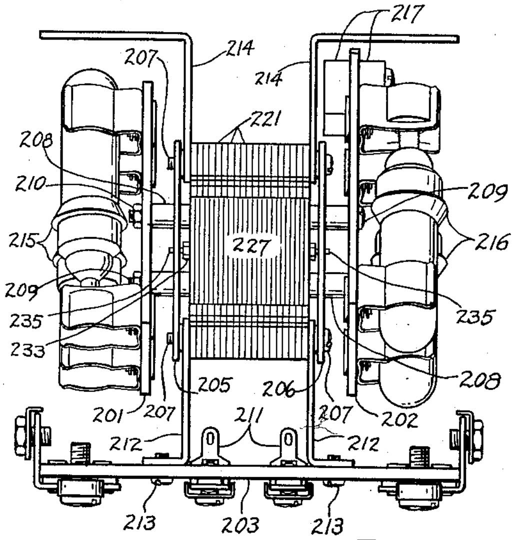

FIG. 15

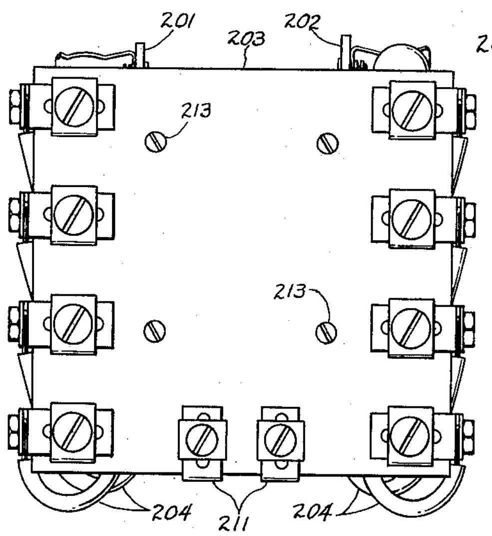

FIG. 13

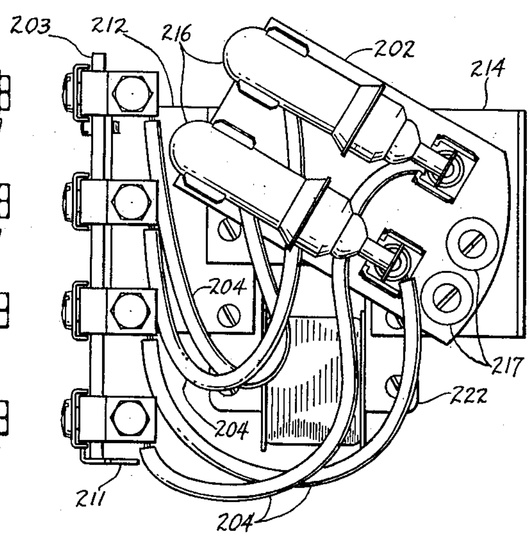

FIG. 14

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United States Patent Office

3,040,147

Patented June 19, 1962

3,040,147

MERCURY RELAY

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Filed Sept. 22, 1958, Ser. No. 762,363
2 Claims. (Cl. 200—112)

This invention relates to mercury relays and more particularly to a relay of the type which incorporates a tiltable mercury switch.

It is a primary object of this invention to provide a tiltable support for a mercury switch and a rotary magnetic actuator therefor.

It is a further object of the invention to attain simplicity, dependability of operation, low cost of manufacture, and economy in actuating power.

It is a further object of the invention to provide, when needed, a plurality of mercury switches actuated by a common rotary magnetic actuator. Such mercury switches may be all normally-open, all normally-closed, or a combination of both types in one unit. By appropriate placement of the several switches relative to each other on the tiltable support, a desired sequence may be established in their circuit control operations.

In a relay made in accordance with this invention, the magnetic actuator includes a rotary member or armature which is pivotally supported between two stationary bearing members. The tiltable switch support or rotor panel is rigidly mounted on the armature without the intervention of a pivotal member or shaft. The means for mounting the rotor panel comprise rigid members secured to the armature and extending therefrom through the plane of one of the aforementioned stationary bearing members, so that the said stationary member is disposed between the armature and the rotor panel. This arrangement obviates the need for a shaft extending through a bearing in the stationary member and supporting the rotor panel at its outer end. Such overhanging shaft would necessarily be of a relatively large diameter to provide adequate support for the mercury switches. If a sleeve journal bearing were used the large diameter would result in a large frictional moment which would increase the required actuating power; and if a ball bearing were used it would increase the cost. In the arrangement according to the present invention the bearing may be made small in diameter, since no shaft which supports an overhanging weight is required.

The switch support mounting and the bearing arrangement described in the foregoing paragraph contribute in a major degree to the attainment of simplicity, dependability, low cost, and economy in actuating power.

Other features of the invention will appear in the detailed description which follows, and its scope will be defined in the appended claims.

The invention will now be described in conjunction with the accompanying drawings, in which:

FIGURE 1 is a front elevation of a relay which embodies the invention.

FIGURE 2 is a side elevation of the relay shown in FIGURE 1.

FIGURE 3 is a top plan view of the relay of FIGURES 1 and 2, a portion of the coil being shown in cross-section to disclose details of the coil terminals.

FIGURE 4 is a perspective view showing the laminated stator of a relay, partly broken away, with one coil flange in position thereon and another coil flange in an intermediate position during the process of assembly thereto.

FIGURE 5 is a rear elevation of a relay showing two mercury switches in the open-circuit position, one of the switches being shown in cross-section.

FIGURE 6 is a rear elevation showing the same mer-

cury switches in the closed-circuit position, one of the switches being shown in cross-section.

FIGURE 7 is a rear elevation of the relay with the mercury switches, the rotor panel, and the flexible leads removed, the armature being in a released position corresponding to the position of FIGURE 5 and being exposed to view through apertures in the rear bearing plate.

FIGURE 8 is a rear elevation similar to FIGURE 7 except that the armature is shown in energized position corresponding to the position of FIGURE 6.

FIGURE 9 is a rear elevation similar to FIGURE 7 except that the rear bearing plate is removed and other parts are broken away to show the magnetic stator and the interior of the coil. (The terminal screws and clamps are omitted for convenience.)

FIGURE 10 is a cross-section on line **10—10** of FIGURES 6 and 8.

FIGURE 11 is a front elevation of a relay incorporating a modified type of terminal and a modified arrangement of the flexible leads.

FIGURE 12 is a side elevation of the relay shown in FIGURE 11.

FIGURE 13 is a front elevation of a relay which incorporates four mercury switches.

FIGURE 14 is a side elevation of the relay shown in FIGURE 13.

FIGURE 15 is a top plan view of the relay of FIGURES 13 and 14, the flexible leads and the dust shield being omitted.

FIGURE 16 is a vertical cross-section of two mercury switches so placed that they provide a "make-before-break" switching sequence.

FIGURE 17 is a vertical cross-section of two mercury switches so placed that they provide a "break-before-make" switching sequence.

Referring now to FIGURES 1 to 10 inclusive, which illustrate a particular embodiment of the invention, U-shaped stator laminations **21** of magnetic material are stacked to form a stator **22**. The upright arms **23**, **24** (FIGURE 9) of the U-shaped stator so formed are provided with arc-shaped recesses **25**, **26** on their inner surfaces. A rotor or armature **27** of magnetic material, which may be composed of laminations **28** (FIGURE 10), is disposed between said upright arms and pivoted on an axis at the center of the arcs formed by said recesses **25**, **26**. Said armature is provided at its ends **29**, **30** with arc-shaped surfaces having a radius which is slightly smaller than the radius of the stator recesses **25**, **26**. When the armature is rotated into the position shown in FIGURE 8 and also shown by the broken lines in FIGURE 9, a small airgap is left between the said surfaces **25** and **29**, and likewise a small airgap is left between the surfaces **26** and **30**. These constitute the working airgaps of the magnetic circuit.

The arms **23**, **24** of the stator **22** are joined by its base portion or core **31** (FIGURE 9), upon which is wound the relay coil **32**. When this coil is excited by a current of suitable magnitude, magnetic flux is thereby caused to flow around the magnetic path and traverse in series the two airgaps between the stator and the armature. Under the influence of this magnetic flux the armature tends to move in such manner as to increase the cross-section of the airgaps, thereby reducing their magnetic reluctance. The armature therefore rotates from the position of FIGURE 7 to that of FIGURE 8, as indicated by the curved arrows in FIGURE 9. The type of airgap shown in these figures may be referred to as a "shear" airgap.

To provide for pivotal support of the armature, a shaft **33** (FIGURES 9 and 10) is inserted through the armature **27**. In the particular embodiment here shown said shaft comprises a main portion of hexagonal cross-section and two end portions **34**, **35** which are round in cross-section and of reduced diameter. The hexagonal portion is pressed into a round hole **36** in the armature **27**.

The reduced round ends **34, 35** of the armature shaft are journalled respectively in the front and rear bridge members **37** and **38**. These members are in the form of plates, each extending between the upright arms **23, 24** of the stator and secured thereto by screws **39, 39**. The rear bridge member **38** preferably is made of nonmangetic metal such as brass. The front bridge member **37** is made of insulating material, such as phenolic plate, and supports connector terminals **65**, which will be described later herein.

A rotor panel **40**, of insulating material, is provided to support the mercury switches **41, 41** and their associated parts. This rotor panel is secured to the armature by screws **42, 42** (FIGURE 10), which extend through holes in the armature, through spacer bushings **43, 43**, and through holes in the rotor panel. Nuts **44** are employed to secure the screws and the bushings to the armature independently of the rotor panel, and nuts **45** secure the rotor panel to the screws **42** to complete the assembly.

It will be seen that the armature lies wholly on one side of the rear bridge member **38**, while the rotor panel lies wholly on the other side thereof. Screws **42** and spacer bushings **43** therefor extend necessarily through the plane of bridge member **38**; and to permit such extension, apertures **46, 46** are provided in bridge member **38**. It will be understood that, in lieu of such apertures, slots or notches extending to the edges of the bridge member may be employed without departing from the spirit of the invention, according to which the rotor panel is secured directly to the body of the armature and not to a central or pivotal shaft.

As illustrated in FIGURES 7 and 8, the walls of apertures **46** may serve as stops which limit the movement of the spacer bushings **43** and thereby limit the rotational movement of the armature. It has been found desirable to provide cushioning at the extremes of this rotational movement, and for this purpose a soft rubber sleeve **47** may be placed over each of the bushings **43**.

The apertures **46** also serve to permit visual inspection of the airgaps between the rotor and the stator. Furthermore, if necessary, shims may be introduced through said apertures into said airgaps for the purpose of adjusting or cleaning the airgaps.

Certain details of the construction of this embodiment remain to be described.

The rotor panel **40** carries one or more mercury switches **41**. Each such switch comprises a steel jacket or tube **48** (FIGURES 5 and 6) which forms one terminal or pole of the switch, a second steel terminal or pole **49**, and a ceramic insulator **50** which joins the two steel members, enclosing a sealed chamber which contains a quantity of mercury **52** (FIGURE 6). The terminal **49** is formed at its inner end into a cup-shaped recess **51** (FIGURE 5) which entraps a small quantity of mercury **53** when the switch is tilted to the open-circuit position, in which position terminal **49** is elevated above the main body of the tube **48** (FIGURE 5). In this position the remainder of the mercury **54** lies at the bottom of tube **48** and is separated from the small body of mercury **53**. The switch is therefore open-circuited. When the switch is tilted to the position shown in FIGURE 6, in which the terminal **49** is depressed and the tube **48** is elevated above it, the mercury **54** flows toward terminal **51** and joins the small body of mercury **53** entrapped therein, forming the combined pool of mercury **52** and closing the switch circuit.

A metallic eyelet **55**, having a flange **56**, is pressed on over each terminal **49** to provide metallic connection to spring clip **57**, which is secured to rotor panel **40** by means of eyelet **58** (FIGURE 10). The other end of switch **41** is supported by spring clip **59**, which makes metallic contact with tube **48** (FIGURES 5 and 6) and is secured to rotor panel **40** by eyelet **60** (FIGURE 10).

Flexible stranded wire leads **61, 61** are provided to make external connections to the movable spring clips **57, 59**. Each lead is made by wrapping the middle of a suitable length of stranded wire around an eyelet **62** (FIGURE 10) and twisting the two halves of the wire together. Eyelet **62** is then spread to clamp the wire firmly in its groove. After the lead end is thus completed eyelet **62** is secured to spring clip **57** or **59**, and simultaneously to panel **40**, by means of eyelet **58** or **60**.

Each flexible lead is protected for virtually its full length by flexible insulating sleeving **64, 64** of rubber, plastic material, or woven fabric. At the end remote from the rotor panel the strands of each lead are divided into two groups and are clamped to one branch **65*a*** of a stationary L-shaped terminal member **65, 65** by means of a clamp member **66, 66** and screw **67, 67** (FIGURES 2, 5, 6). The other branch **65*b*** of each terminal member **65** is secured to the insulating front plate **37** by means of rivets **68, 68** or other suitable fastening means. A clamp member **69** and a screw **70** are provided for electrical connection of an external wire to branch **65*b*** of each terminal member **65**.

The flexible connections and terminals for all of the mercury switch poles are constructed as described above with reference to numerals **60** to **70** inclusive.

Reference will now be made to FIGURES 1, 2, 3, 4, and 9, which disclose details in the construction of the relay exciting coil. As will be seen in FIGURES 4 and 9, the base portion **31** of the U-shaped stator **22** is flanked on its upper surface by the upright arms **23, 24** and is flanked on its lower surface by two small shoulders **71, 72**. These flanking components are utilized to confine the coil flanges **73, 74**.

The coil flanges **73, 74** are made of vulcanized sheet fibre or like material, each flange having a rectangular opening adapted to receive and enclose the base portion **31** of the stator. A slit **75** extends from the outer periphery of the flange into the rectangular opening. Preferably this slit **75** is placed midway along the thickness of the stator, in order that rigidity may be imparted to the flange when the coil winding presses the flange areas on both sides of said slit firmly against the retaining wall presented by the upright arm of the stator.

FIGURE 4 shows coil flange **74** in position around the base portion **31** of the stator and in contact with the retaining walls presented by the upright arm **24** and lower shoulder **72**. FIGURE 4 also shows coil flange **73** during the process of assembly to the stator. In this process the coil flange is deformed by twisting and bending its four sides, opening its slit far enough to permti it to slip over the base portion **31**. After slipping over said base portion the coil flange is flattened, closing its slit, and then is slid to its final position in contact with the retaining walls.

After the two coil flanges **73, 74** are assembled to the stator and slid to their final positions, they are locked in said final positions by a layer of tape **76** (FIGURE 9) wrapped around the base portion **31**. Said tape is preferably of adhesive-coated insulating material. In lieu of said tape, a winding of insulating yarn may be applied.

If desired, a strip of adhesive-coated insulating tape **77** may be applied over the slit of each coil flange, as shown in FIGURE 9, to hold the flange in its proper position prior to winding and to prevent the wire from catching on the edge of the flange during winding.

The components **73, 74, 76**, and **77**, assembled to the stator in accordance with the foregoing description, constitute a simple bobbin for the coil winding **32**. Said bobbin is low in cost, provides adequate insulation and retention of the coil winding, and occupies a relatively small proportion of the space available for the coil. In the last-mentioned respect said bobbin affords a marked advantage over a molded bobbin which is split into two halves to permit its assembly to the stator.

In the process of winding the coil **32**, the stator is mounted on a suitable mandrel and is revolved about an axis parallel to the length of the base portion **31**. The equipment employed in this operation is not illustrated in the drawings and will not be described in further detail herein, since it does not constitute a part of the present invention.

After the completion of the coil winding **32**, a protective layer **78**, FIGURES 3 and 9, may be applied to its exterior. This protective layer may be either a wrap of insulating tape or a winding of yarn made of cotton or other suitable material.

In the particular embodiments shown in FIGURES 1 to 12 inclusive, two screw terminals are secured to the exterior of the coil for connection thereto. As shown in FIGURE 3, the terminal screws **79, 79** engage tapped holes in terminal lugs **80, 80** which are secured to insulating strip **81** by rivets **82** or other suitable fastening means. This terminal assembly is placed on the exterior of the winding and is secured thereto firmly by the protective wrap or winding **78**. A strip of insulating material preferably is interposed between the coil winding and said terminal assembly, as shown at **83**, FIGURE 3, to guard against contact between the winding and the rivets **82**. Before the protective layer is completed, the ends of the coil winding are soldered to the terminal lugs **80**.

The terminal lugs **80** may be prevented from turning relative to their supporting strip **81** by the binding action of the protective layer **78**. As additional protection against such turning, each lug **80** may be provided with a bent tongue as shown at **84** in FIGURE 3, or may be provided with a second rivet (not shown). Means for fixing the position of the terminal assembly are provided in the form of notches or recesses **85** (FIGURE 4) in the edges of the coil flanges, said notches being adapted to receive the terminal lugs as shown in FIGURES 2 and 3.

It will be understood that the terminal lugs and screws described in the foregoing paragraphs may be replaced by solder lugs, or that the lugs may be secured to the exterior of the coil by the protective layer without the aid of the supporting strip **81**. Alternatively, wire leads may be employed in lieu of the terminal lugs, said leads being secured or anchored to the coil by the protective layer.

If desired, a dust shield **86** may be placed above the armature to prevent the entry of foreign particles into the airgap. This dust shield may be of resilient material and may be sprung into place, being held in position by notches in the upright arms **23, 24** as shown in FIGURE 9. For further protection against the entry of foreign particles, an additional dust shield (not shown) may be placed underneath the armature.

Two flat pieces **87, 87** are employed to prevent the flexible leads **64** from coming into contact with the rotor panel **40** and thereby impeding its movement. Said plates **87** are interposed between the rear bridge member **38** and the upright stator arms **23, 24**, to serve additionally as spacers between said members. Said spacers provide clearance between the rear bridge member and the rear surface of the rotor **29**, in order that the movement of the rotor shall not be impeded by contact with the rear bridge member.

Spacers **88, 88** are placed around screws **39** and interposed between the front bridge member **37** and the upright stator arms. Said spacers provide clearance between the front bridge member and the heads of screws **42**, in order that the movement of the rotor shall not be impeded by contact between said screw heads and the front bridge member.

Mounting brackets **89, 89** are secured to the stator by screws **90, 90** to permit the completed relay to be mounted on an external support in a vertical plane.

Reference will now be made to FIGURES 11 and 12, which show a modification which differs from the embodiment shown in FIGURES 1 to 10 in the arrangement of the flexible wire leads and connection terminals. In this modification the terminals, shown at **101, 101**, are secured to the front panel **102** by bent tabs **103** passing through holes in said front panel. Each terminal has a tapped hole into which a screw **104, 104** is inserted. Each said screw retains in position on its terminal **101** a lug **105, 105** which is crimped to the flexible wire lead, forming a solderless connection. An insulating sleeve **106, 106** encloses each lug **105**. The flexible insulating tubing which protects the flexible lead enters the sleeve **106** and is secured therein by crimping as at **107, 107**.

The two upper flexible leads **108, 108** are arched over the top as may be seen in FIGURES 11 and 12. The two lower leads **109, 109** are passed through the open space or window between the front panel and the coil.

In this modification, the flat plates **87** which appear in FIGURES 2 to 10 are not needed to guard the flexible leads from interference with the rotor panel. Accordingly, said flat plates are replaced by spacers **110** (FIGURE 12).

In another modification, which is illustrated in FIGURES 13, 14, and 15, the relay structure incorporates four mercury switches. In the particular embodiment shown in the drawings two rotor panels **201, 202** are placed in vertical planes perpendicular to the plane of the front panel **203**, and are mounted in such manner as to permit their rotation about a horizontal axis parallel to the plane of said front panel. By this arrangement convenient placement of the flexible leads **204, 204** is achieved, as well as their unimpeded movement.

In this embodiment the laminations **221** of stator **222** are placed in a vertical plane perpendicular to the front panel midway between the rotor panels **201, 202**, as shown in FIGURE 15. Left and right bridge members **205, 206** are secured to the stator by screws **207, 207** and support the ends **235, 235** of rotor shaft **233**, which in turn supports rotor **227**, as may be understood by reference to the foregoing description of the embodiment shown in FIGURES 1 to 10. Apertures (not shown) similar to those shown at **46, 46** in FIGURES 7 and 8 are provided in bridge members **205, 206** for the passage therethrough of spacers **208, 208** and screws **209, 209** which, in cooperation with nuts **210**, complete the assembly of the rotor panels to the rotor.

In this embodiment the coil is not accessible from the front as in the embodiments previously described. For this reason a terminal assembly secured directly to the coil is not utilized, but instead a pair of wire leads (not shown) is employed to connect the coil to a pair of terminals **211** secured to the front panel **203**.

Brackets **212, 212** are employed to secure the stator to the front panel, as may be seen in FIGURES 14 and 15. Said brackets **212** are secured to stator **222** by screws **207**, and they are secured to front panel **203** by screws **213, 213**.

Mounting brackets **214, 214** are secured to the stator as shown in FIGURES 14 and 15, to permit the completed relay to be mounted on an external support in a vertical plane.

The particular embodiment shown in FIGURES 13, 14, and 15 includes two "normally-open" mercury switches **215**, assembled to rotor panel **201**, and two "normally-closed" mercury switches **216**, assembled to rotor panel **202**.

It has been found in practice that the center of gravity of the "normally-closed" switches **216** is farther forward than that of the "normally-open" switches **215**. To facilitate biasing the mercury switches toward their normal positions (coil not energized), which is the position in which they are shown, counterweights 217 are attached to rotor panel **202**, as may be seen in FIGURES 14 and 15.

FIGURE 16 illustrates an arrangement of two mercury switches placed on a rotor panel in a mutual angular relation such that, as the panel is rotated, the "normally-open" switch closes before the "normally-closed" switch opens. The rotor panel is shown in an intermediate position, in which both switches are closed. This is known as a "make-before-break" arrangement.

FIGURE 17 illustrates an arrangement of two mercury switches placed on a rotor panel in a mutual angular relation such that, as the panel is rotated, the "normally-closed" switch opens before the "normally-open" switch closes. The rotor panel is shown in an intermediate position, in which both switches are open. This is known as a "break-before-make" arrangement.

In the foregoing disclosure, a particular form of relay, in which mercury switch tubes are tilted by magnetic flux in a "shear" airgap and are returned by gravity, has been shown and described. However, it should be understood that the invention, as set forth in the appended claims, is equally applicable to the movement of objects other than mercury switch tubes, and that many departures from the arrangement and construction herein shown may be made without departing from the spirit of the invention. Among such possible departures a few will be listed herein:

The airgap may be made non-uniform in length, tapered or stepped to provide special torque characteristics. Similar effects may also be achieved by varying the width of the stationary or moving pole faces so as to control the rate of change of gap area with respect to movement.

The stator may be so placed that its "upright arms" may be horizontal, or inverted, or in some intermediate position. Other changes in the geometry of the stator and rotor, and of their associated parts, may be introduced. The opposing surfaces of the airgaps may be made flat instead of cylindrical, so that the flux between them will extend axially instead of radially.

In connection with the preceding paragraph it should be noted that with a flat airgap, provision could readily be made for adjustment of the length of the airgap, which has an important bearing upon efficiency and other characteristics.

The stator and the armature or rotor may be made of molded or cast magnetic material instead of laminations. The use of molded or cast material would facilitate the use of flat airgaps, should the latter become desirable.

By employing permanent magnets in the armature or in the stator, the device may be made responsive to polarity reversals.

In lieu of a coil flange made of pliable material having a narrow slit and adapted to be deformed and sprung into position over the stator core as shown in FIGURE 4, a U-shaped flange adapted to slip over the core without deformation may be employed. The gap between the arms of the U-shaped flange may be closed by tape or by overlapping with a similar U-shaped flange slipped over the core from the opposite side. An assembly employing flanges of this type comes within the scope of the invention; the underlying purpose being the avoidance of a split molded bobbin with its attendant disadvantages of high cost and space consumption.

Alternatively, a winding of the "self-supporting" type, without coil flanges, may be employed.

Numerous other departures may be made in the arrangement of component parts and in the details of construction while retaining the substance of the invention, which is defined in the claims.

I claim:

1. In a relay, a stator having two arms, an armature disposed between said arms, a switch actuating member, a first bridge member joining said arms and disposed between the armature and the switch actuating member, a second bridge member joining said arms, the armature being disposed between said two bridge members, means for pivotally supporting the armature from said two bridge members, a plurality of supporting members secured to both the armature and the switch actuating member, said supporting member being disposed symmetrically with respect to said means for pivotally supporting the armature, a plurality of apertures traversing the first bridge member, each of said supporting members passing through one of said apertures, and a switch responsive to rotary movement of said actuating member.

2. In a relay, a stator having two arms, an armature disposed between said arms, a switch carrier, a first bridge member joining said arms and disposed between the armature and the switch carrier, a second bridge member joining said arms, the armature being disposed between said two bridge members, means for supporting the armature from the bridge members and permitting its rotation about a substantially horizontal axis, a plurality of supporting members symmetrically disposed about said axis and secured to both the armature and the switch carrier, a plurality of apertures traversing the first bridge member, each of said supporting members passing through one of said apertures, a switch mounted upon the carrier, said switch being responsive to gravitational change effected by its rotation about a substantially horizontal axis, a terminal supported by the second bridge member, and a flexible electrical conductor extending from the switch carrier to said terminal.

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