United States Patent

Greenwood

[15] **3,670,130**

[45] **June 13, 1972**

[54] **IMPROVEMENTS IN ELECTROSTATIC RELAYS**

[72] Inventor: **John Christopher Greenwood**, Pinner, England

[73] Assignee: **International Standard Electric Company**, New York, N.Y.

[22] Filed: **Feb. 24, 1970**

[21] Appl. No.: **13,450**

[30] **Foreign Application Priority Data**

March 7, 1969 Great Britain......................12,221/69

[52] **U.S. Cl.**.................................**200/183**, 335/49, 200/181

[51] **Int. Cl.**....................................**H01h 29/00**, H01h 57/00

[58] **Field of Search**.......................335/3, 49, 56; 200/152, 9

[56] **References Cited**

UNITED STATES PATENTS

2,545,669	3/1951	Meyer	200/152 X
2,830,159	4/1958	Varner	200/152
2,744,980	5/1956	Bellamy	335/49
2,802,918	8/1957	Boyle	335/49 X

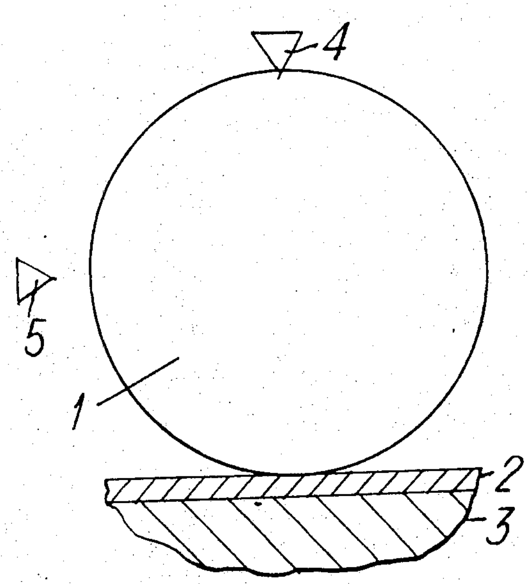
Primary Examiner—Herman J. Hohauser

Attorney—C. Cornell Remsen, Jr., Walter J. Baum, Percy P. Lantzy, J. Warren Whitesel, Delbert P. Warner and James B. Raden

[57] **ABSTRACT**

A relay is provided which includes a drop of conducting liquid, for example mercury, and means for subjecting the drop to an electro-static field to effect movement of the drop between at least two positions. This movement causes the conductive drop to interconnect different contacts, switching the relay from one state to another.

21 Claims, 9 Drawing Figures



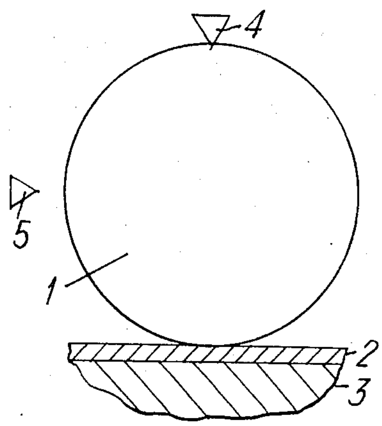


Fig. 1A.

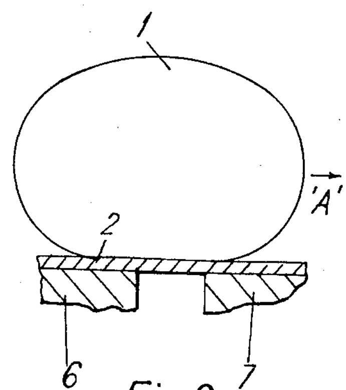


Fig. 2.

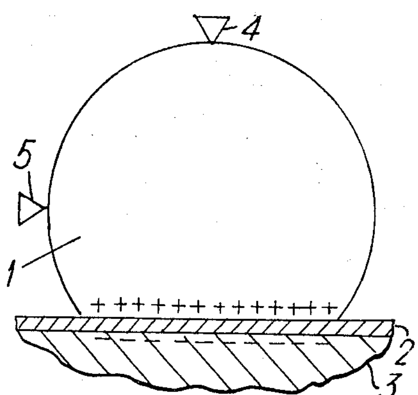


Fig. 1B

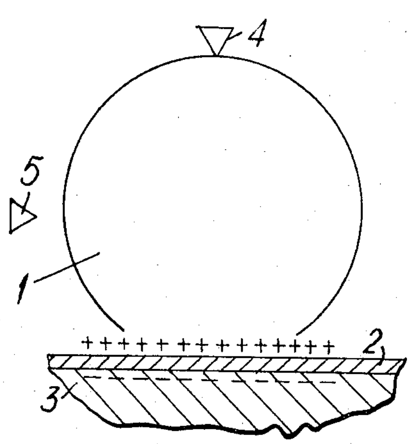


Fig. 1C.

Inventor
J. C. Greenwood - 5
By D. J. Warner
Attorney

PATENTED JUN 13 1972 3,670,130

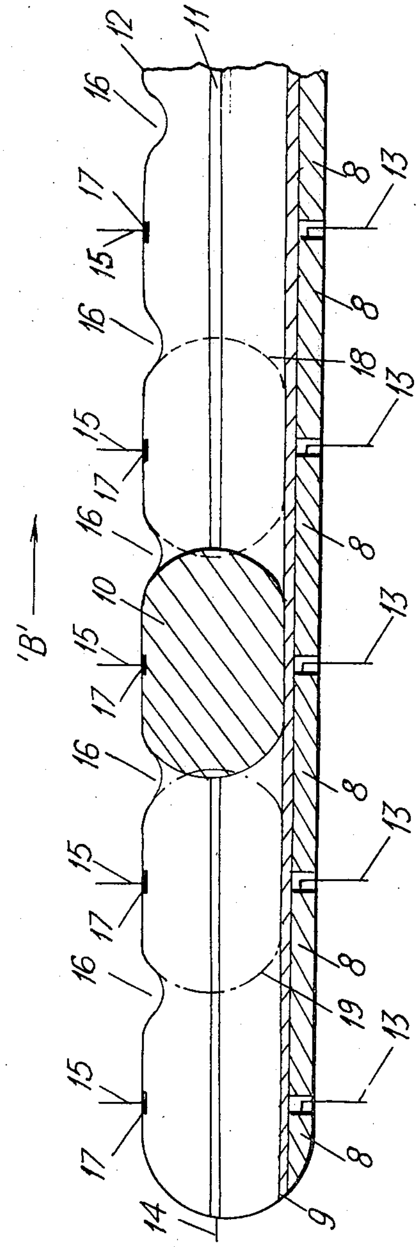


Fig.3.

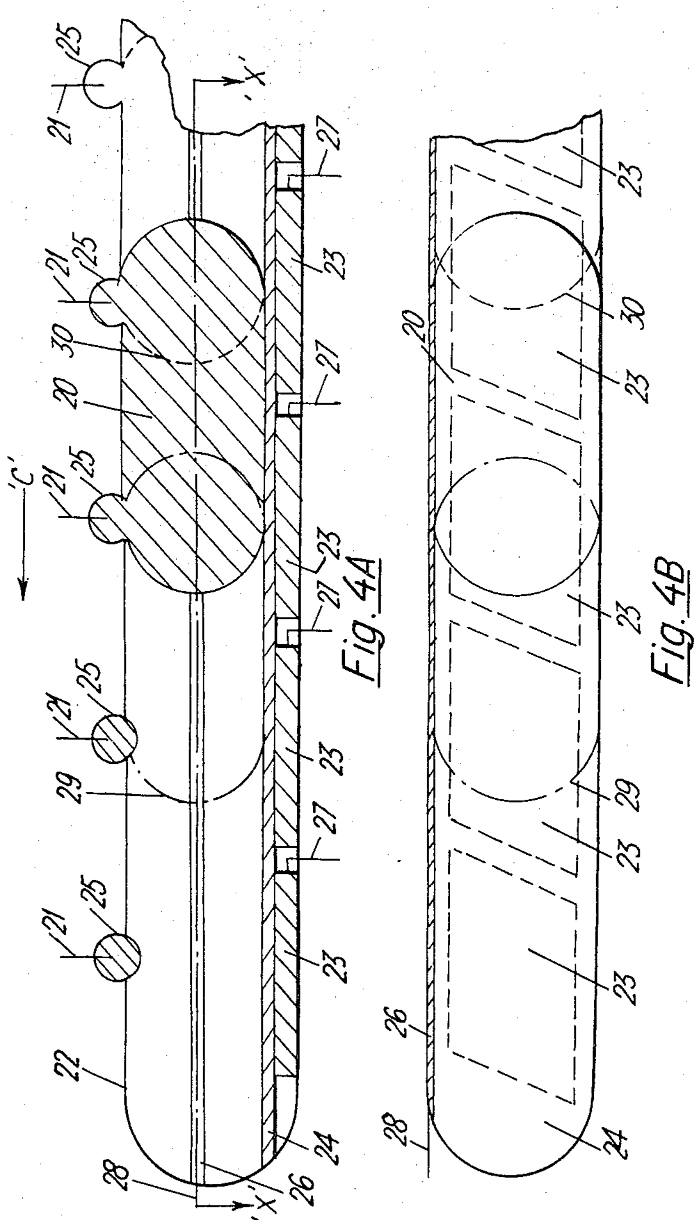


Fig. 4A

Fig. 4B

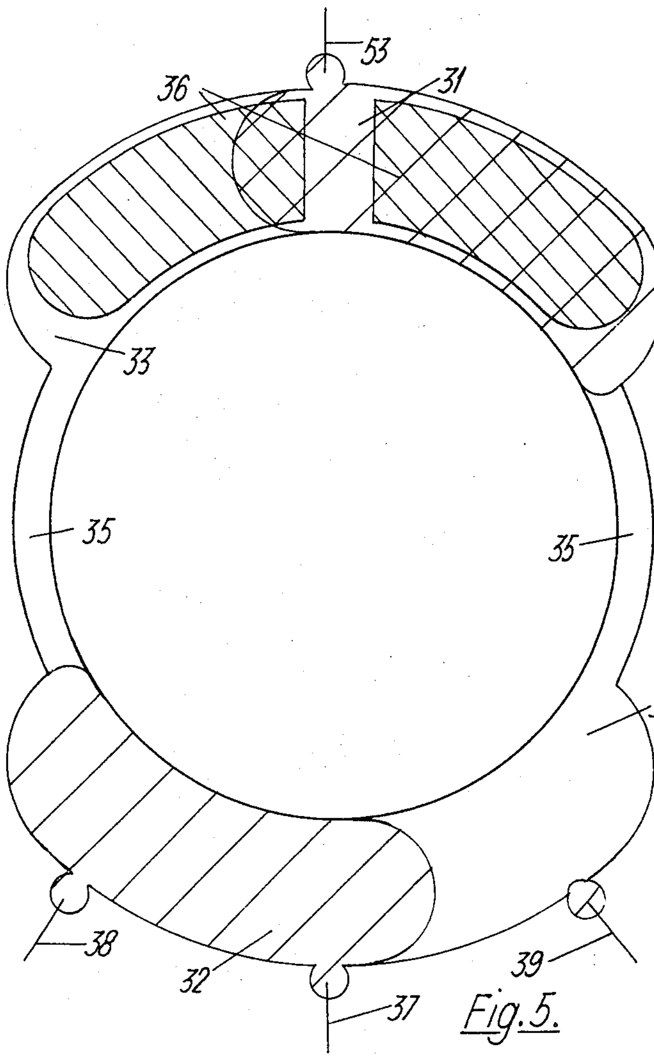

53
36
31
33
35
35
34
38
32
37
39

Fig.5.

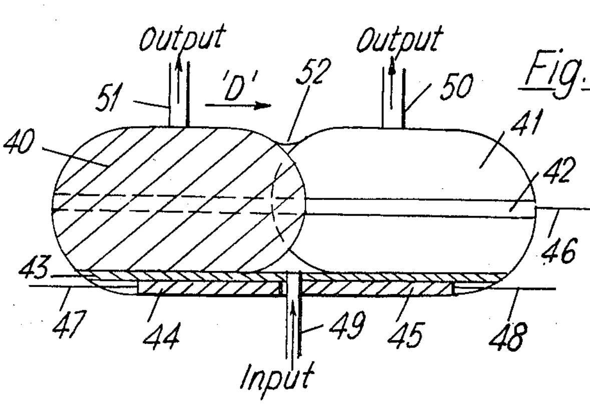

Output
Output
51
'D'
52
50
40
41
42
46
43
47
44
49
45
48
Input

Fig.6.

IMPROVEMENTS IN ELECTROSTATIC RELAYS

The invention relates to a relay.

The invention provides a relay including a drop of conducting liquid, and means for subjecting said drop to an electrostatic field to effect movement of same between at least two positions, said movement causing the relay to switch from one state to at least one other state.

The foregoing and other features according to the invention will be better understood from the following description with reference to the accompanying drawings, in which:

FIGS. 1A to 1C diagrammatically illustrate the effects of an electrostatic field on a drop of conducting liquid,

FIG. 2 diagrammatically illustrates a method of causing a drop of conducting liquid to be moved in a plane by means of an electrostatic field,

FIG. 3 diagrammatically illustrates a sectioned side elevation of one arrangement of the relay according to the invention,

FIGS. 4A and B respectively, diagrammatically illustrate a sectioned side elevation and a sectioned plan view of a modified version of the relay according to FIG. 3,

FIG. 5 diagrammatically illustrates a sectioned plan view of another arrangement of the relay according to the invention, and

FIG. 6 diagrammatically illustrates a sectioned side elevation of a further arrangement of the relay according to the invention.

The surface tension of mercury is of the order of 4.6×10^{-5} J.cm^{-2} and a dielectric film can be made that can store surface energies of this order, for example an anodized tantalum film can be made that can have a capacity of 0.1 μF cm^{-2} and will withstand a potential of 100 volts applied across it.

Now, the surface energy stored $= \frac{1}{2}\, cv^2$.

The surface energy stored by an anodized tantalum film under the conditions cited above

$$= \tfrac{1}{2} \times 10^{-7} \times 10^{4}\ \mathrm{J.cm^{-2}}$$
$$= 5 \times 10^{-4}\ \mathrm{J.cm^{2}}.$$

Referring to FIG. 1A, a drop 1 of mercury is illustrated resting on the surface of a film 2 of tantalum oxide which is formed by anodizing the surface of a tantalum metal substrate 3 and under these conditions the shape of the drop is that shape which has the minimum energy. As shown in FIG. 1A, the drop is in contact with an electrode 4 and out of contact with an electrode 5.

When a voltage is applied between the drop 1 and the substrate 3, the surface energy of the mercury where it is in contact with the dielectric film 2 is opposed by the energy in the electrostatic field which is generated by the applied voltage. The surface of the drop of mercury in contact with the tantalum oxide film 2 will therefore tend to increase so as to increase the capacitances of the film and thus cause a change in the shape of the drop.

This effect, as illustrated in FIG. 1B, is used in a manner such that the drop makes contact with the electrode 5 and breaks the contact with the electrode 4 when the drop is distorted by the electrostatic field. This arrangement can therefore form the basis of a relay having the advantage that there is no contact wear due to switching the relay.

With this arrangement the returning force is the surface tension of the drop which is unlikely to change with age and the drive power would be very small. However, in the form illustrated such a relay has the disadvantage that the input is capacitively coupled to the output, at least in the on state, and is affected by gravity.

It was found by experiment that a d.c. voltage applied between the drop and the substrate caused the drop to be distorted in a manner as outlined in a preceding paragraph, but it was also found that the effect was only a transient one i.e. the drop flattened out when the d.c. voltage was applied but immediately returned to its original shape as illustrated in FIG. 1C. Also, when the capacitor formed by the drop 1, film 2 and substrate 3 is discharged, the drop momentarily flattens out again.

It is thought that the drop immediately returns to its original shape due to the fact that the surface of the tantalum oxide film 2 is capable of holding a charge in the absence of a conductor and that once the drop has transferred the charge to this surface, there is no longer any force on it to retain the drop in its flattened form.

However, with an a.c. voltage applied between the drop and the substrate, the drop remains in its distorted or flattened form.

It should be noted that other conducting liquids for example gallium, indium, alkaline metals such as sodium/potassium compounds, ionic solutions i.e. solutions of a salt in water, and mercury amalgams also exhibit the characteristics outlined in preceding paragraphs when subjected to an electrostatic field. However, the use of gallium, indium and alkaline metals is limited by temperature considerations since they are only liquid at temperatures that may be inconveniently high. Also, the alkaline metals are highly reactive thereby giving further limitations to their use. The main disadvantage of ionic solutions is that they will react with the electrodes and cause them to corrode although the corrosion problem is minimized when the relay is operated by an A.C. voltage.

It should also be noted that the substrate 3 may be of metals other than tantalum, for example aluminum may be utilized in which case a film 2 of aluminum oxide could be formed as the dielectric material by anodizing the surface of the aluminum substrate.

Some of the above mentioned disadvantages can be avoided if the electrostatic field is used to move the drop of conducting liquid instead of distorting it in order to effect the switching of a relay from one state to at least one other state.

A method of causing a drop of conducting liquid to be moved in a plane by means of an electrostatic field is diagrammatically illustrated in the drawing according to FIG. 2 wherein the drop 1 is illustrated resting on the surface of a film 2 of a dielectric material which is formed on a surface of two electrodes 6 and 7.

In operation, a voltage applied between the drop 1 and the electrode 7 causes the surface energy of the drop where it is in contact with that part of the dielectric film 2 directly above the electrode 7 to oppose the energy in the electric field which is generated by the applied voltage.

The surface of the drop in contact with that part of the dielectric film directly above the electrode 7 will therefore tend to increase so as to increase the capacitance of this part of the film thereby causing the drop to move in the direction of the arrow 'A.' Conversely, if the voltage is applied between the drop 1 and the electrode 6 then the drop will move in the opposite direction to the arrow 'A.' This arrangement can therefore be used in a relay and has the advantage that the relay can be made to latch and only consume power while it is switching from one state to another. The fact that the drop of liquid returns to its original shape after switching is therefore of no significance.

Also, more complex types of switching can be achieved with this arrangement, for example a drop of conducting liquid can be made to scan along a number of contacts either sequentially or in any other desired manner. The relay diagrammatically illustrated in part in a sectioned side elevation in the drawing according to FIG. 3 utilizes this scanning feature and basically includes within an insulating housing member 12, a number of metal electrodes 8, for example of tantalum metal, a film 9 of dielectric material, for example of tantalum oxide formed on a surface of each of the electrodes 8, a drop 10 of a conducting liquid which is in contact with the film 9, a number of metal electrodes 17 which are secured to or formed in the inner surface of the housing member 12 and a strip contact 11 which is secured to or formed in the inner surface of the housing member 12 such that it is at all times in contact with the drop 10 of conducting liquid. The housing member 12 for example of glass, is provided with a series of depressions 16 which are arranged such that each one of them is positioned directly opposite a separate one of the electrodes 8. Metal contact leads **13**, **14** and **15** are respectively provided for the electrodes **8**, the strip contact **11** and the electrodes **17** which pass through and are secured in the walls of the housing member **12**.

In practice, the electrodes **8** and the strip contact **11** would be connected to a voltage source (not shown in the drawing) respectively by means of the contact leads **13** and **14** in a manner such that a voltage pulse may be applied between the strip contact **11** and any one of the electrodes **8**. The electrodes **15** and the strip contact **11** would be connected to an output circuit or circuits (not shown in the drawing) in any desired configuration.

In operation, the relay is switched from one state to another state by causing the drop **10** of conducting liquid to move in the same direction as or the opposite direction to the arrow 'B' such that after it has been moved it respectively occupies the position indicated by the dotted line **18** or the chain dotted line **19**.

The movement in the direction of the arrow 'B' is effected by applying a voltage pulse between the strip contact **11** and the electrode **8** situated below the right hand part of the drop **10** illustrated in cross-hatched detail in FIG. **3**. This causes the drop **10** to move in the direction of the arrow 'B.' The duration of the voltage pulse is such that the surface of the drop **10** in contact with that part of the dielectric film **9** directly above the electrode **8** via which the pulse is applied, increases by an amount sufficient to cause at least half the volume of the liquid content of the drop to be moved past the depression **16** which is situated on the right hand side of the drop. When this state is reached the voltage pulse need not be sustained since the momentum of the drop will be sufficient to cause it to latch into the position indicated by the dotted line **18**. Thus in order to effect the movement in the opposite direction to the arrow 'B,' the voltage pulse of the required duration is applied between the strip contact **11** and the electrode **8** situated below the left hand part of the drop **10** illustrated in cross-hatched detail in FIG. **3**.

It can therefore be seen from the above that any desired switching action can be achieved by causing the drop of conducting liquid to scan the electrodes **17** in a manner such that the desired switching action is effected, for example the electrodes may be sequentially scanned to effect a sequential switching action by sequentially applying voltage pulses between the strip contact **11** and the electrodes **8**.

A modified version of the relay is diagrammatically illustrated in FIGS. **4A** and **4B** which show, respectively, a sectioned side elevation and a sectioned plan view of the relay. The construction and operation of this relay arrangement is basically the same as the relay according to FIG. **3** except that at each position of the drop **20** two metal electrodes **21** are connected together, the arrangement of the electrodes **23** as illustrated in FIG. **4B** is different, and a different latching mechanism for the drop **20** is utilized.

As illustrated in FIGS. **4A** and **4B**, the relay basically includes within an insulating housing member **22** the wall of which is provided with a number of protrusions **25**, a number of metal electrodes **23**, for example of tantalum metal each one of which is situated directly opposite a separate one of the protrusions **25**, a film **24** of dielectric material, for example of tantalum oxide formed on a surface of each of the electrodes **23**, the drop **20** which is in contact with the film **24**, the metal electrodes **21**, each one of which passes through and is secured within the wall of a separate one of the protrusions **25**, and a strip contact **26** which is secured to or formed in the inner surface of the housing member **22** such that it is at all times in contact with the drop **20** of conducting liquid. Metal contact leads **27** and **28** which are respectively provided for the electrodes **23** and the strip contact **26** pass through and are secured in the walls of the housing member **22**.

In practice, the electrodes **23** and the strip contact **26** would be connected to a voltage source (not shown in the drawing) respectively by means of the contact leads **27** and **28** in a manner such, that a voltage pulse may be applied between the strip contact **26** and the electrodes **23**. The electrodes **21** and the strip contact **26** would be connected to an output circuit or circuits (not shown in the drawing) in any desired configuration.

In operation, the switching of the relay from one state to another state is effected by causing the drop **20** to be moved in the same direction as or in the opposite direction to the arrow 'C' such that after it has been moved it respectively occupies the position indicated by the chain dotted line **29** or the dotted line **30**.

The movement in the direction of the arrow 'C' to achieve a switching action is effected by first applying a voltage pulse between the strip contact **26** and the electrode **23** situated below the left hand part of the drop **20** illustrated in cross-hatched detail in FIG. **4A**, which will cause the drop **20**, in a manner as previously described to move in the direction of the arrow 'C.' The duration of this voltage pulse is arranged in conjunction with the shape of the electrodes **23** such that it causes the surface of the drop **20** in contact with the dielectric film **24** to increase by an amount such that part of the surface of the drop is situated directly above part of the electrode **23** which is adjacent to the left hand end of the electrode **23** via which the voltage pulse is applied i.e. the surface area of the electrodes **23** must overlap in the plane of movement of the drop in a manner such that the surface of the drop can be influenced by the electrostatic field associated with one electrode **23** and while under this influence be situated above at least part of an adjacent electrode **23**, situated in the direction of movement of the drop. After the application of the first voltage pulse a second voltage pulse should then be applied between the strip contact **26** and the said adjacent electrode **23** which must be of sufficient duration to cause a continuation of the movement of the drop to a position where it will latch into the position indicated by the chain dotted line **29**. Since, as previously stated, the change of shape of the drop is a transient effect it is necessary for the second voltage pulse to be applied immediately the duration of the first voltage pulse ceases or alternatively the two voltage pulses could be arranged to at least partially overlap each other.

Thus in order to effect the movement in the opposite direction to the arrow 'C,' a first voltage pulse of the required duration should be applied between the strip contact **26** and the electrode **23** situated below the right hand part of the drop **20**, illustrated in cross-hatched detail in FIG. **4A**, and then either during or after the application of the first voltage pulse a second voltage pulse should be applied between the strip contact **26** and the electrode **23** adjacent to the right hand end of the electrode **23** via which the first voltage pulse is applied.

In order to avoid the effects of gravity on the relay and the lack of isolation between its input and output terminals, the relay arrangement diagrammatically illustrated in FIG. **5** in a sectioned plan view may be utilized. With this arrangement two equal sized drops **31** and **32** of conducting liquid are utilized, each one of which is enclosed within an annular cavity **33**, **34**. The cavities **33** and **34** are interconnected by means of channels **35** and the motion of one of the two drops of conducting liquid is transmitted to the other one of the two drops by means of a suitable electrically insulating inert fluid, for example an inert gas, contained within the channels **35** and that volume of each of the cavities **33** and **34** not occupied by the drops **31** and **32**. Contact leads **37**, **38** and **39** are formed in the wall of the cavity **34** by means of which the switching action is effected and a contact lead **53** is formed in the wall of the cavity **33** which is utilized in conjunction with contact electrodes **36** to effect the movement of the drop **31**.

The drop **31** is caused to move from one end of the cavity **33** to the other end thereof by means of an electrostatic field established between the drop **31** i.e. via the contact lead **53** and either of the contact electrodes **36**. This movement causes the drop **32** to be moved thereby effecting an interconnection between the contact electrode **37** and either the contact electrode **38** or the contact electrode **39**.

In practice, the relay illustrated in FIG. 5 can be quite small i.e. a few millimeters across and can therefore be manufactured in arrays utilizing photolithographic techniques. For such a manufacturing process the starting material will be a flat insulating substrate for example of glass, onto a major surface of which the metal contact electrodes 36, for example of aluminum, are deposited. A film of dielectric material, for example of silicon nitride is then formed over the electrodes 36 and the remainder of the major surface.

The next stage of the manufacturing process involves the provision of another flat insulating substrate for example of glass having the cavities 33 and 34 and the channels 35 formed in one of the major surfaces thereof. The contact electrodes 37 to 39 and 53, in the form of metal wire, are next provided and fitted into the substrate such that they extend into the cavities 34 and 33 in the correct position i.e. the electrodes 38 and 39 would be situated one at each end of the cavity 34, the electrode 37 would be situated in the center of the cavity 34 and the electrode 53 would be situated in the center of the cavity 33, and such that they also extend from the other one of the major surfaces of the substrate to effect the connection thereto of an output circuit or circuits.

The desired amount of conducting liquid is then metered into each of the cavities after which the two substrates are bonded together by a suitable adhesive in an inert liquid atmosphere such that the surface of the dielectric film is in contact with that major surface of the substrate having the cavities therein and the contact electrodes 36 are in register with the associated cavities. Since the bonding of the two substrates is effected in an inert fluid atmosphere the channels 35 and that volume of each of the cavities 33 and 34 not occupied by the drops 31 and 32 will contain the inert fluid and the adhesive must be capable of setting in the absence of air. However, the bonding of the two substrates need not necessarily be effected in an inert fluid atmosphere, the inert fluid could be metered into the channels 35 and the unoccupied volumes of the cavities 33 and 34 after the bonding operation in which case the adhesive need not necessarily exhibit the property of being capable of setting in the absence of air.

Alternatively, the substrate having the cavities therein can be formed by two flat insulting insulating substrates, one of which would have apertures in the form of the cavities 33 and 34 formed therethrough and the channels 35 which interconnect the cavities formed in one of the major surfaces thereof. The other major surface of this substrate is then bonded to the surface of the dielectric by a suitable adhesive such that the contact electrodes 36 are in register with the associated cavities.

The other one of the two flat insulating substrates which would have the contact electrodes 37 to 39, in the form of metal wire, fitted therein such that they are located at positions corresponding to the positions of the cavities 34 and such that they extend outwardly from each of the major surfaces thereof is bonded to the major surface of the said one of the two substrates having the channels 35 therein by a suitable adhesive after the desired amount of conducting liquid had been metered into each of the cavities. This bonding operation may be effected in an inert liquid atmosphere or the inert liquid could be metered into the channels 35 and the unoccupied volumes of the cavities after the bonding operation.

When the sandwiched structure of the array of relays is complete by any one of the methods outlined in the preceding paragraphs the structure is then divided up into the individual relays by a suitable cutting operation.

It should be noted that it is not an essential feature that the cavities should be annular, they could in fact be in any elongated form.

Due to the small size and low power dissipation of this type of relay much higher packing densities than are achieved by its electromagnetic equivalent can be obtained. Also on account of its small size and minimal drive requirements this type of relay is compatible with integrated circuits and it could therefore share the same substrate as silicon chips and various thick and thin film elements.

With the relays outlined in the preceding paragraphs, the relay contacts are at all times 'wetted' with the conducting liquid, for example, with the relays according to FIGS. 4 and 5 a certain amount of conducting liquid is retained within the cavity protrusions that completely surrounds the relay contacts, thus when the drop of conducting liquid is moved between any two positions to cause the relay to switch from one state to another state, any flashing that may occur due to this switching action will only result, in the case of mercury, in the formation of mercury vapor since the flashing will only occur between the drop of mercury and the mercury which wets the relay contacts. However, if the relay contacts are not wetted the flashing would result in the formation of a vapor of the material of the relay contacts thereby cause a certain amount of contamination.

A modified version of the relay outlined in preceding paragraphs can form part of a fluidic circuit. FIG. 6 diagrammatically illustrates one such arrangement wherein a drop 40 of conducting liquid is contained within a cavity 41 and in contact with a strip contact electrode 42 formed in the cavity wall and a layer 43 of dielectric material formed on the surface of contact electrodes 44 and 45 contained within the cavity 41. Metal contact leads 46, 47 and 48 are respectively provided for the electrodes 42, 44 and 45. An input pipe or channel 49 for the fluid input to the relay opens out into the cavity 41 and output pipes or channels 50 and 51 which also open out into the cavity 41 provide the fluid output ports for the relay.

As with the relay according to FIG. 3 the cavity 41 is provided with a depression 52 which is utilized to latch the drop 40 into its switch position. In order to facilitate the operation of this relay in the same manner as the relay according to FIG. 3 the surface area of the electrodes 44 and 45 are arranged to overlap e.g. in a manner as shown in FIG. 4B, in the plane of movement of the drop such that the surface of the drop in the position illustrated in FIG. 6 can be influenced by the electrostatic field associated with a voltage pulse applied between the electrode 45 and the electrode 42. Similarly when in the other position, the surface of the drop can be influenced by the electrostatic field associated with the voltage pulse applied between the electrode 44 and the electrode 42.

In operation, the fluid input to the cavity 41, when the drop is in the illustrated position, passes out of the cavity via the output pipe or channel 50. When it is required to direct the fluid output via the pipe or channel 51, the drop is moved in the direction of the arrow 'D' in a manner as previously described until its takes up the other of its two positions. When in this other position the fluid input passes out of the cavity via the output pipe or channel 51. It will be appreciated that such a fluidic relay would only be capable of being operated in the presence of relatively low pressure fluid since the pressure of the fluid must not be capable of distorting the shape of the drop by an amount such that it becomes out of contact with its drive electrode 44, 45. Also the pressure exerted by the fluid must be capable of being overcome by the electrostatic forces which are generated to effect the movement of the drop.

It will be appreciated that in the construction of the relays outlined in the preceding paragraphs that it is not an essential feature that the film of dielectric material should bridge the gaps between the electrodes on surfaces of which the film is formed. In practice these electrodes would be very closely spaced and the only requirement is that those surfaces of the electrodes exposed to the conducting liquid should be covered with dielectric material in order to effect the most efficient capacitive effect.

It is to be understood that the foregoing description of specific examples of this invention is made by way of example only and is not to be considered as a limitation on its scope.

I claim:

1. A relay including a first drop of conductive liquid within a cavity formed by a wall of dielectric material, a plurality of flat metal plates forming capacitor plates immediately outside one surface of the wall, the drop of liquid functioning as a capacitor plate within the wall, the drop of liquid responding to elec-

trostatic fields between respective ones of said capacitor plates and itself to effect movement of the drop of liquid from one position to another, said movement causing a loss of contact between at least one pair of relay contacts and the making of contact between another pair of relay contacts, an inert fluid within said cavity in a space between said first drop of conductive liquid and a second drop of conductive liquid, said inert liquid forming means through which the movement of said first drop of conductive liquid is transmitted to and effects the movement of the second drop of conductive liquid, a change of position of said second drop causing changes in conductivity between additional pairs of contacts.

2. A relay as claimed in claim 1 wherein the movement of said first drop is transmitted to said other drop by means of an electrically insulating inert fluid.

3. A relay as claimed in claim 1 wherein said second drop is contained within another cavity each end of which opens into a separate one of the ends of said first mentioned cavity via an interconnecting passage, said another cavity being provided with at least one relay contact at each of a plurality of positions, each contact being secured to or formed in the inner surface of the cavity and being adapted, at each of said positions, to make electrical contact with said second drop.

4. A relay including a first drop of conductive liquid within a cavity formed by a wall of dielectric material, a plurality of metal plates forming capacitor plates immediately outside the wall, the drop of liquid functioning as a capacitor plate, the drop of liquid responding to electrostatic fields between respective ones of said capacitor plates and itself to effect movement of the drop of liquid from one position to another, said movement causing a loss of contact between at least one pair of relay contacts and the making of contact between another pair of relay contacts, an inert fluid within said cavity in a space between said first drop of conductive liquid and a second drop of conductive liquid, said inert liquid forming means through which the movement of said first drop of conductive liquid is transmitted to and effects the movement of the second drop of conductive liquid, a change of position of said second drop causing changes in conductivity between additional pairs of contacts, said capacitor plates being positioned on a major surface of a flat insulating substrate, said cavity and a plurality of supply and relay contacts associated therewith being formed in another substrate, said another substrate being bonded to the surface of said common layer when the drops of conducting liquid have been metered into the said cavities and the said electrically insulating inert fluid occupying that volume of the said cavities not occupied by the said drops and the volume of the cavity interconnecting passages, and wherein electrical contact leads for said supply contact, each of said other plates, and each of said relay contacts are provided.

5. A relay including a first drop of conductive liquid within a cavity formed by a wall of dielectric material, a plurality of metal plates forming capacitor plates immediately outside the wall, the drop of liquid functioning as a capacitor plate, the drop of liquid responding to electrostatic fields between respective ones of said capacitor plates and itself to effect movement of the drop of liquid from one position to another, said movement causing a loss of contact between at least one pair of relay contacts and the making of contact between another pair of relay contacts, an inert fluid within said cavity in a space between said first drop of conductive liquid and a second drop of conductive liquid, said inert liquid forming means through which the movement of said first drop of conductive liquid is transmitted to and effects the movement of the second drop of conductive liquid, a change of position of said second drop causing changes in conductivity between additional pairs of contacts, wherein the capacitor plates are provided on a major surface of a flat insulating substrate, wherein said cavity is formed by part of the surface of said common layer, an aperture formed in another flat insulating substrate such that it is in correct register with other plates, and part of the major surface of a further flat insulating substrate which is bonded to the other major surface of said another substrate when the drops of conducting liquid have been metered into the said cavity and the said electrically insulating inert fluid occupies that volume of the said cavity not occupied by the said drops and the volume of the cavity interconnecting passages and wherein electrical contact leads for said supply contact, each of said other plates, and each of said relay contacts are provided.

6. A relay as claimed in claim 1 including a plurality of cavities providing a number of positions into which the drop of liquid may move and including means for latching said drop into each of said positions.

7. A relay as claimed in claim 6 wherein said latching means are provided by increasing the cross-sectional area of the cavities at the positions where said relay contacts and said supply contact are located.

8. A relay including a drop of conductive liquid within a cavity formed by a sealed tube of dielectric material, said drop of liquid forming a capacitor plate, electrical supply contacting means terminating within the cavity and extending throughout the cavity parallel to the axis of the tube and through end walls of the tube to provide continuous electrical contact with said drop, a plurality of capacitor plates aligned outside said cavity and along one side thereof, means for applying potential across individual capacitor plates and said drop to produce electrostatic fields, said electrostatic fields producing mechanical forces causing said drop of liquid to move from a position near a low electrostatic field to a position near a high electrostatic field within the cavity, and at last one relay contact provided at each of said positions, said relay contact being extended through the wall of the tube to a position enabling contact with the drop of liquid on a side of the tube opposite to the side along which the capacitor plates are aligned, each said relay contact being adapted at each of said positions to make electrical contact with said drop of conductive liquid when the drop is in a certain position.

9. A relay as claimed in claim 8 wherein electrical contact leads for each of said relay contacts are provided which pass through and are secured within the wall of said hollow insulating member.

10. A relay as claimed in claim 8 wherein said sealed tube of dielectric material includes means for latching said drop into each of said positions.

11. A relay as claimed in claim 10 wherein said latching means are provided by reducing the cross-sectional area of the cavity formed by the hollow insulating member at a point midway between said positions.

12. A relay as claimed in claim 11 wherein a single relay contact is provided at each of said positions.

13. A relay as claimed in claim 10 wherein said latching means are provided by increasing the cross-sectional area of the cavity formed by the sealed tube at two points at each of said positions.

14. A relay as claimed in claim 13 wherein two relay contacts are provided at each of said positions, each of said relay contacts being located at a point where the said cross-sectional area is increased.

15. A relay as claimed in claim 8 wherein the conductive liquid consists of a material in the liquid state taken from a group of materials including mercury, gallium, indium, alkaline metals, ionic solutions, and mercury amalgams.

16. A relay as claimed in claim 8 wherein the conductive liquid consists of an alkaline metal in a sodium/potassium compound.

17. A relay as claimed in claim 8 wherein said common layer consists of dielectric material taken from a group of materials including silicon nitride, aluminum oxide and tantalum oxide.

18. A relay as claimed in claim 17 wherein the said other plates consist of materials selected from aluminum or tantalum metal when said common layer is respectively of aluminum oxide or tantalum oxide.

19. A relay as claimed in claim 8 wherein the hollow insulating member is of glass.

20. A relay as claimed in claim 4 wherein said insulating substrates are of glass.

21. A relay as claimed in claim 8 wherein said drop is contained within a cavity in a manner such that it is at all times in contact with the tube of dielectric material, wherein said cavity is provided with a fluid inlet port and wherein said cavity is provided with at least one fluid outlet port at each of said positions, said drop being adapted when at each of said positions to isolate the outlet port thereat from the said inlet port thereby directing the fluid input to the other outlet port or ports of the relay.

* * * * *