Dec. 10, 1935. R. P. MATTERN 2,023,740

ELECTRICAL RESISTANCE APPARATUS

Filed May 16, 1934

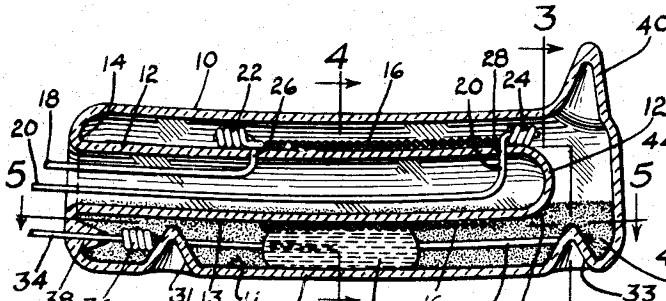

Fig. 2

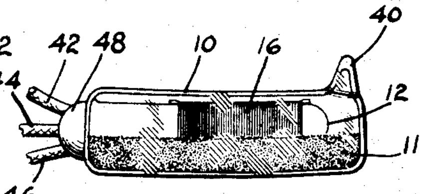

Fig. 1

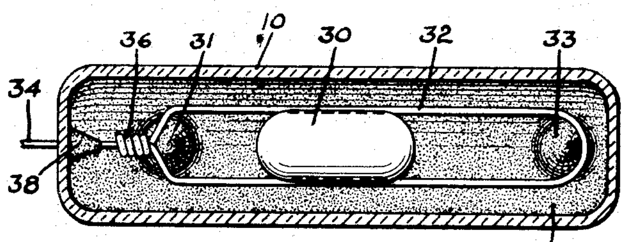

Fig. 5

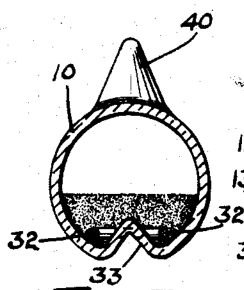

Fig. 3

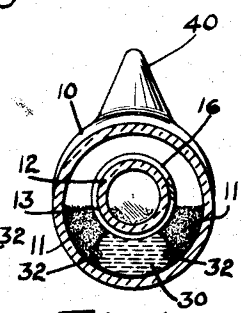

Fig. 4

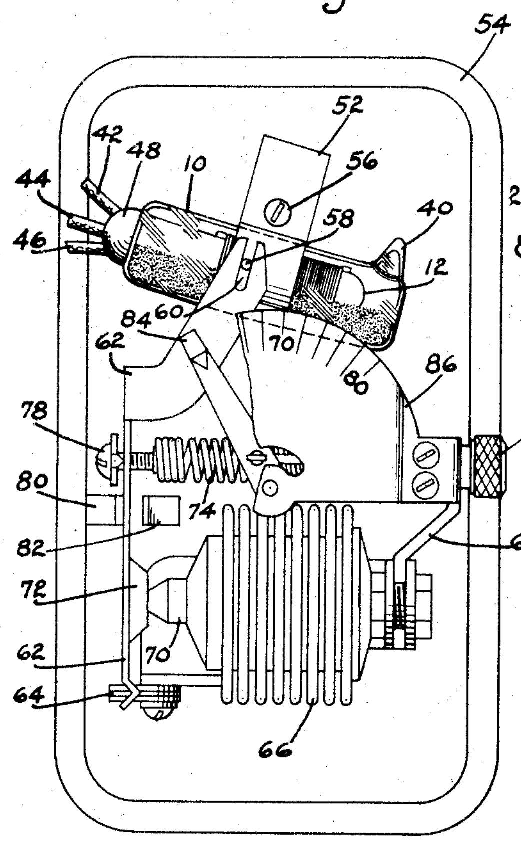

Fig. 6

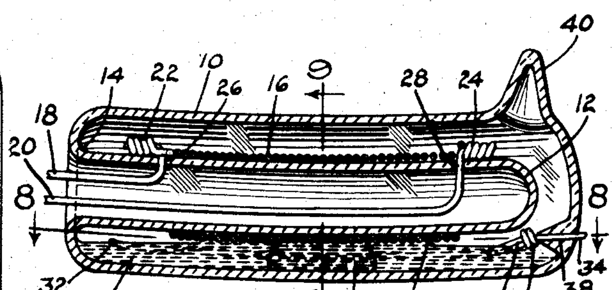

Fig. 7

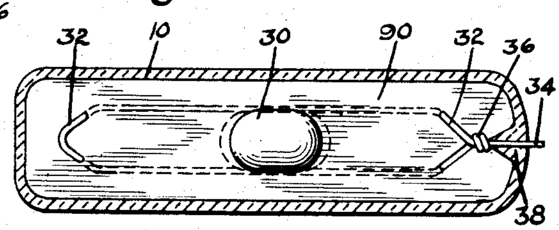

Fig. 8

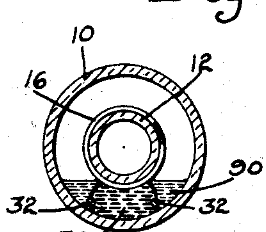

Fig. 9

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ELECTRICAL RESISTANCE APPARATUS

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Application May 16, 1934, Serial No. 725,958

6 Claims. (Cl. 201—55)

This invention relates in general to electrical resistance apparatus adapted to vary the resistance in an electrical circuit. Common forms of such apparatus are potentiometers and rheostats.

Electrical apparatus of this type usually has an electrical resistance element over which a movable contact mechanically frictionally slides to vary the resistance between one or both ends of the resistance element and the movable contact. In such devices, there is considerable electrical resistance between the movable contact and the resistance element which is known as "contact resistance". This contact resistance is different for different positions of the movable contact. It also changes from time to time for the same position because dust and other foreign particles get under the contact and also because the contacting surfaces tend to corrode with age. There is also a tendency for the movable contact and resistance element to burn and pit because of a poor contact and thus further increase the contact resistance. This contact resistance is very detrimental to the life and accuracy of such apparatus.

When such devices are operated manually or where a large amount of power is available for operating them, a heavy contact pressure may be used and, as a result, the contact resistance does not seriously affect their accuracy or usefulness. However, they are not satisfactory when operated automatically by means responsive to changes in a physical condition, such as thermostats and other devices which produce a very small amount of power. If a heavy contact pressure is used to overcome the detrimental contact resistance, then they do not readily respond to the automatic means and are therefore unsatisfactory. If a light contact pressure is used to make them readily respond to the automatic means, the contact resistance becomes quite large and seriously interferes with the accuracy and usefulness of the device. A light contact pressure often causes the contact and element to burn and pit which increases the amount of power required to move the contact over the element. Such light contact pressure also makes it easy for dust and other foreign particles to get under the contact and thus cause an open circuit and also cause burning and pitting of both the contact and element.

In an application filed May 16, 1934 by Sylvanus C. Shipley, Serial No. 725,971, it has been proposed to replace this movable mechanical contact with a body of mercury and to seal the mercury and resistance element in a glass envelope. The mercury and resistance element in that application are provided with external circuit connections, and the parts are so arranged that upon tilting the envelope the mercury contacts with various parts of the resistance element to vary the resistance between the external circuit connections.

This invention is a further improvement on potentiometers and rheostats of the fluid contact type which makes them more sensitive to relatively weak automatic actuators, and also makes them more definite and dependable in their operation.

One of the objects of this invention is to provide an improved variable electrical resistance apparatus which can be successfully operated automatically with a minimum of power.

Another object of this invention is to provide an improved potentiometer or rheostat type of device in which the movable contact is a fluid that will not adhere to the surface over which it moves.

Another object of this invention is to provide an improved potentiometer or rheostat type of device in which the movable contact is a conducting fluid that can be made to assume any desired position with respect to the resistance element with a minimum of power.

Another object of this invention is to provide an improved potentiometer or rheostat type of device in which the movable contact is a body of conducting fluid that is not obstructed or hindered from moving freely from one end of the resistance element to the other and yet will assume and remain in any desired position.

Other objects and advantages reside in certain novel features of the construction, arrangement, and combination of the parts which will be hereinafter more fully described and particularly pointed out in the appended claims, reference being had to the accompanying drawing forming a part of this specification, and in which:

Fig. 1 is a side elevation of a liquid contact potentiometer.

Fig. 2 is an enlarged vertical section of the potentiometer shown in Fig. 1, but having the flexible leads and insulating compound omitted.

Fig. 3 is a vertical sectional view taken on line 3—3 of Fig. 2.

Fig. 4 is a vertical sectional view taken on line 4—4 of Fig. 2.

Fig. 5 is a horizontal sectional view taken on line 5—5 of Fig. 2.

Fig. 6 shows a thermostatic actuating mechanism operating the potentiometer shown in Figs. 1 to 5.

Fig. 7 is an enlarged vertical section of a modification of the potentiometer shown in Figs. 1 to 5.

Fig. 8 is a horizontal sectional view taken on line 8—8 of Fig. 7.

Fig. 9 is a vertical sectional view taken on line 9—9 of Fig. 7.

In Figures 1 to 6 inclusive of the drawing there has been disclosed a preferred form of the invention for the purpose of explanation and description. In the specific form shown, the container or envelope 10 is of soft glass but may be made of various other materials well-known in the mercury switch art. The envelope 10 has an elongated member projecting therein. This projection is here shown as a tube 12 which is preferably of soft glass and integral with the envelope 10. The envelope 10 and the tube 12 are preferably made up separately and then fused together at 14, but it is not essential that they be fused together for other means of supporting the tube 12 inside the envelope 10 may be employed.

An elongated resistance element 16 is supported on the inwardly projecting member such as the tube 12. The resistance element 16 is shown in the drawing as a coil of wire wound on the outer face of the tube 12 and therefore within the envelope or container 10. This wire may be made of commercial "Chromel A" or "Chromel C" resistance wire which is a nickel-iron-chromium alloy, but any resistance material which will not deteriorate in the presence of mercury will be satisfactory. The resistance element 16 has "Dumet" leading-in wires 18 and 20 attached to its ends at 22 and 24. "Dumet" is known in the art to be copper clad invar electro-welded together. The "Dumet" leading-in wires 18 and 20 are sealed through the glass tube 12 at 26 and 28 in accordance with the well-known practice in the mercury switch art. It is not essential that the resistance element 16 be wound on the tube 12 since it is only necessary that it be properly supported within the envelope 10, preferably parallel with the lower wall thereof, in which case the tube 12 may be dispensed with.

When the device is used as a rheostat it is obviously not necessary to use both leading-in wires 18 and 20, in which case, either one may be omitted. But when used as a potentiometer, both leading-in wires 18 and 20 are essential.

A movable body of conducting fluid 30 herein shown as mercury is in the envelope 10 and in engagement with the resistance element 16. This fluid makes a good electrical contact with the resistance element and therefore gives a very low contact resistance. The mercury 30 is arranged to move within the envelope 10 and in doing so to engage various points on or portions of the resistance element 16.

In the lower part of the envelope 10 there is provided means to limit or obstruct the movement of the mercury 30 which may take the form of projections or bosses 31 and 33 in the path of the mercury 30. These bosses 31 and 33 may be placed on the floor of the envelope 10 but are here shown as integral inward projections produced by deforming the glass envelope 10. It will be obvious to those skilled in the art that other means of limiting or obstructing the travel of the mercury 30 may be provided. The bosses 31 and 33 prevent the mercury 30 from traveling beyond the ends of the resistance element 16 during normal operation. If the resistance element 16 is positioned near one end of the envelope 10 then it is only necessary to use one of these bosses as a stop to limit the movement of the mercury in one direction since the end of the envelope will so act in the other direction.

The external circuit for the mercury 30 may be provided by the lower wall of the envelope when it is made of conducting material but, where as here shown, the envelope is of glass, means must be provided to cause the mercury 30 to complete an electrical circuit between the resistance element 16 and some external circuit connection. Therefore, in this preferred form, an electrode 32 is provided which is in engagement with the mercury 30 and which may be made of various electrode materials, such as molybdenum, tungsten, stainless steel, nickel, or iron. The electrode 32 may be made in various forms but is here shown in the form of two parallel spaced conductors conveniently made in the form of an elongated loop around either or both of the bosses 31 and 33. A "Dumet" leading-in wire 34 is welded to the electrode 32 at 36 and is also sealed at 38 through the wall of the glass envelope 10. This method of welding electrodes and leading-in wires and sealing the leading-in wires through a glass envelope is well-known in the mercury switch art. By this arrangement of the bosses 31 and 33 and the looped electrode 32 there is defined or provided a passageway or runway for the mercury 30 over the lower inside surface or floor of the envelope 10. When the envelope 10 is tilted back and forth the mercury 30 moves over the above-described runway within the looped electrode 32 and between the spaced bosses 31 and 33. As the mercury 30 moves over this runway, it continuously makes contact with the electrode 32 and at the same time makes contact with various parts or sections of the resistance element 16. The various parts and elements are so arranged and proportioned that a minimum of resistance is offered to the flow of the mercury 30 over the runway and at the same time the mercury 30 is permitted to make a good electrical contact with the electrode 32 and various portions of the resistance element 16.

The inside lower surface 11 of the envelope 10 including the bosses 31 and 33 is roughened to provide a roughened-surface runway for the mercury 30. The outer surface 13 of the tube 12, or at least the lower portion thereof, is also roughened. The purpose of roughening these surfaces is to reduce to a minimum the adhesion or surface tension between the mercury 30 and these surfaces and thus make the mercury 30 more readily assume a new position upon a slight tilting of the envelope 10. The roughened surface of the tube 12 also makes it easier to wind the resistance element 16 on the tube 12. These roughened surfaces may be produced by etching the glass with a solution of the following composition:

	Percent
Ammonium bifluoride	30
Sodium carbonate	7
Ammonium carbonate	15
Hydrofluoric acid 48%	43
Water	5

This etching solution produces a roughened or frosted surface on the glass similar in appearance to the ordinary "frosted" electric light bulb. It is recognized that other means may be used to produce such a surface without departing from the scope of this invention.

After the above elements are assembled, the envelope 10 may be exhausted of air and then sealed off at 40, or the envelope may be refilled with hydrogen or some other arc-supressing gas before sealing. This prevents dust or other foreign matter from interfering with the contact and also prevents corrosion and oxidation of the contacting surfaces. The "Dumet" leading-in wires 18, 20, and 34 are equipped with insulated flexible circuit-connecting wires 42, 44, and 46 respectively. The connections between these leading-in wires and the flexible wires are covered with insulating compound or cement 48 which closely adheres to the envelope 10 as disclosed in Phelan et al. Patent No. 1,826,470 granted October 6th, 1931.

The envelope 10, tube 12, and electrode 32 are all slightly curved for the purpose of providing a concave runway for the mercury 30 which will cause the body of mercury 30 to assume a definite position for each position of the envelope 10. If the envelope 10 were straight then the mercury 30 would only have two stable positions and these would be at the bosses 31 and 33 for, if the envelope 10 were tilted sufficiently to cause the mercury 30 to move at all, it would move the full length of the runway or from one of the bosses to the other. The curvature of the envelope 10 is just sufficient to cause the mercury 30 to have a stable or definite position for each position of the envelope 10. By slightly tilting the envelope 10, the body of mercury 30 will move accordingly and thus change the point at which the electrode 32 is connected to the resistance element 16. The resistance between the wires 18 and 20 is fixed by the amount of resistance in the resistance element 16 and remains constant, but the resistance between either of the wires 18 or 20 and the wire 34 is determined by the position of the body of mercury 30. With the mercury 30 in the position shown in Fig. 2 the resistance between the wires 18 and 34 is less than the resistance between the wires 20 and 34. But with the envelope 10 in the position shown in Fig. 6, the mercury 30 is against the boss 33 and the resistance between the wires 18 and 34 is relatively large as compared to the resistance between the wires 20 and 34.

In Fig. 6, there is shown an automatically operating mechanism for tilting the envelope 10. In the form here shown, this mechanism automatically responds to a physical condition such as temperature. The envelope 10 is secured in a clip 52 which is pivoted to a base 54 by a stud 56. The clip 52 is equipped with a pin 58 which cooperates with a slot 60 in the upper end of an operating lever 62. The lower end of the lever 62 is formed to cooperate with a pivot 64 which is secured to the base 54. A volatile fluid temperature-sensitive bellows 66 is secured at one end to a bracket 68 which is fixed to the base 54. The other end of the bellows 66 is equipped with a pin 70 which cooperates with a socket 72 on the operating lever 62. The lever 62 is also acted upon by a tension spring 74 one end of which is attached to the base 54 through an adjustable or temperature-setting stud 76 and the other end is attached to the bracket 62 by a stud 78. On the base 54 there are two stops 80 and 82 to limit the travel of the upper end of the bracket 62. The spring 74 tends to hold the lever 62 against the stop 82 but the bellows 66 expanding on a temperature rise tends to force the lever 62 against the stop 80. The tension of the spring 74 which may be varied by the adjusting stud 76 determines the temperature at which the pressure in the bellows 66 will just balance the tension of the spring 74 and cause the lever 62 to assume a position half-way between the stops 80 and 82. When the lever 62 is in this mid-position, the envelope 10 will be in the horizontal position. If the temperature increases the bellows 66 will move the lever 62 towards the stop 80 which will in turn move the left end of the envelope 10 up and cause the mercury 30 to move towards the boss 33. If the temperature decreases, the pressure in the bellows 66 will decrease and the spring 74 will move the lever 62 towards the stop 82 which will in turn move the right end of the envelope 10 up and cause the mercury 30 to move toward the boss 31. The adjusting stud 76, which varies the tension of the spring 74, also moves the pointer 84 over the graduated dial 86 permitting the mechanism to be set for any desired temperature.

The curvature of the envelope 10 causes the mercury 30 to assume a definite position for each position of the operating lever 62 and thus make contact with a particular part or portion of the resistance element 16 to place a definite amount of resistance in the circuit. This curvature of the envelope 10 is such that when the envelope is tilted to a new position the inertia of the body of mercury 30 will not cause the mercury 30 to move beyond a position corresponding to the new position of the envelope 10.

Because of the roughened or frosted surface which is engaged by the mercury 30, the adhesion or surface tension between the mercury and the surfaces with which it contacts is reduced to a minimum. This permits the mercury 30 to move freely to a new position upon the slightest tilting of the envelope 10. The arrangement of the electrode 32 in the form of parallel spaced conductors offers a minimum of obstruction to the flow of mercury 30 and thus additionally aids in making the device more sensitive to weak actuators such as thermostatic devices. The bosses 31 and 33 prevent the body of mercury 30 from traveling beyond the ends of the resistance element 16 during normal operation of the device. Without the bosses, there would be a possibility of the circuit being broken entirely by the mercury traveling beyond the end of the resistance element. These bosses also permit the use of a shorter resistance element than would be possible with a construction that depended on the ends of the envelope to act as stops for the body of mercury.

In the modification shown in Figs. 7 to 9, the various parts are numbered to correspond with similar parts of the device shown in Figs. 1 to 5. This modification depends upon the elongated-looped electrode 32 to define the passageway or runway for the conducting fluid over the floor of the envelope 10 because the envelope 10 is not equipped with the bosses. The envelope 10 contains a sufficient quantity of a liquid 90, such as benzine, glycerine, alcohol, or a very light petroleum base lubricating oil to cover the body of mercury 30. This liquid acts like a lubricant for the body of mercury 30 which causes the mercury readily to move when the container 10 is slightly tilted. The use of this liquid obviates the necessity of roughening the surface over which the mercury travels. After the parts are assembled, the envelope 10 may be sealed off at 40. When the mercury 30 is covered by a liquid 90, it is not necessary to evacuate the container 10 before it is sealed. This modification may be operated by the mechanism shown in Fig. 6 or by any other means which is adapted to operate the device shown in Figs. 1 to 5.

Potentiometers and rheostats of the construction shown in either Fig. 2 or Fig. 7 require only a very small amount of power to change the position of the body of conducting fluid and thus change the resistance in the circuit. The electrical resistance between the fluid and the resistance element which is known as "contact resistance" is very low because the fluid makes a good contact with the element. Also, this contact resistance remains constant because the elements are hermetically sealed and prevent dust and other foreign matter from interfering with the contact. Since the elements are hermetically sealed, they do not corrode or oxidize with use or age.

Although the devices here shown and described are in the form of potentiometers, it will be apparent that they may be used as rheostats by only using wires **18** and **34** or wires **20** and **34**, in which case one or the other of the leading-in wires **18** and **20** may be omitted.

The envelope **10** may be made of metal and the resistance element **16** insulated therefrom, in which case the electrode **32** can be dispensed with and the wire **46** attached to the envelope **10**.

While but two embodiments of the invention are herein shown and described, it is to be understood that various modifications thereof will be apparent to those skilled in the art without departing from the spirit and scope of the invention set forth in the following claims.

Having thus described my invention, what I claim as new and desire to secure by United States Letters Patent is:

1. A device of the class described comprising, an elongated container, an elongated supporting member in said container extending longitudinally thereof, a resistance element mounted on said supporting member, an electrode extending along the lower portion of the container in the form of an elongated loop, and a body of conducting fluid movable within the loop to make contact between the electrode and various portions of the resistance element.

2. A device of the class described, comprising in combination, a hermetically sealed curved glass envelope having a reentrant curved tube extending from one end of the envelope longitudinally toward the other end thereof, a resistance element wound on the reentrant tube, a projection on the inside of the envelope in the floor near each end thereof, spaced electrodes extending adjacent the floor thereof and abutting said projections, and a body of conducting fluid in the envelope arranged to be guided by said electrodes to move back and forth between said projections and thus complete a circuit between the electrodes and various parts of the resistance element as the envelope is tilted.

3. A device of the class described comprising in combination, a hermetically sealed curved glass envelope having a reentrant curved tube extending from one end of the envelope longitudinally toward the other end thereof, a resistance element wound on the tube and having external connections, a projection on the inside of the envelope in the floor near each end thereof, an electrode entering the envelope and extending adjacent the floor thereof in the form of an elongated loop around the projections, and a body of conducting fluid in the envelope arranged to move back and forth in the loop and be guided thereby and thus complete a circuit between the electrode and various parts of the resistance element as the envelope is tilted.

4. A device of the class described comprising in combination, a hermetically sealed curved glass envelope having its inside lower portion frosted, a reentrant curved tube integral with the envelope extending from one end of the envelope longitudinally toward the other end thereof and having its enclosed surface frosted, a resistance element wound on the frosted surface of the tube and having external connections, a projection on the inside of the envelope in the floor near each end thereof, an electrode entering the envelope and extending along the floor thereof in the form of an elongated loop around the projections, a body of conducting fluid in the envelope arranged to move back and forth in the loop and thus complete a circuit between the electrode and various parts of the resistance element as the envelope is tilted, and means for tilting the envelope whereby the resistance is varied between the electrode and each of the external connections.

5. A device of the class described comprising a container, a supporting member in said container, a resistance element mounted on said supporting member, spaced electrodes extending along the lower portion of the container, and a body of conducting fluid movable between said spaced electrodes to make contact between the electrodes and various portions of the resistance element.

6. A device of the class described, comprising in combination, a sealed glass envelope having a reentrant tube extending from the envelope longitudinally toward the other end thereof, a resistance element wound on the reentrant tube, an electrode extending adjacent the floor of the envelope and being in the form of an elongated loop, and a body of conducting fluid in the envelope arranged to be guided by the loop of the electrode and complete the circuit between the electrode and various parts of the resistance element as the envelope is tilted.

RAYMOND P. MATTERN.