April 8, 1958 E. E. O. ENGEL ET AL 2,830,160

CONTROL SWITCHES

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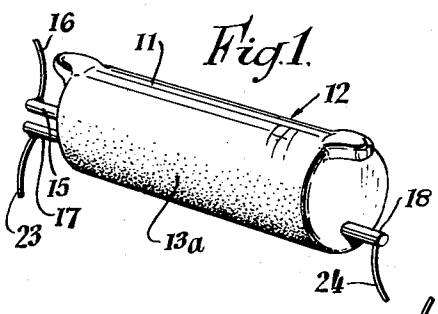


Fig. 1.

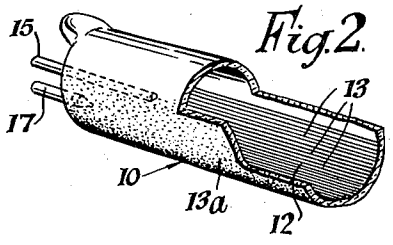


Fig. 2.

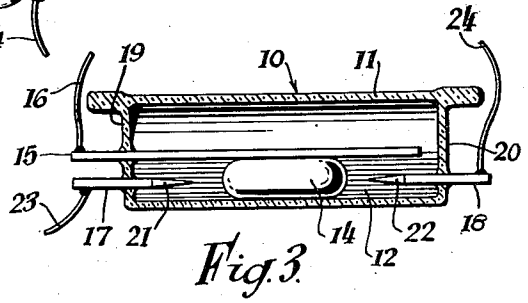


Fig. 3.

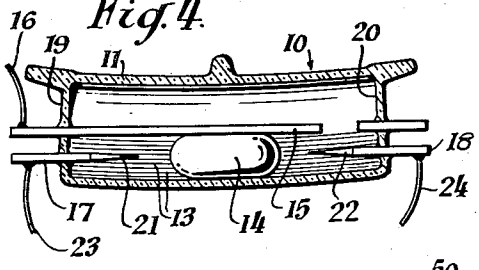


Fig. 4.

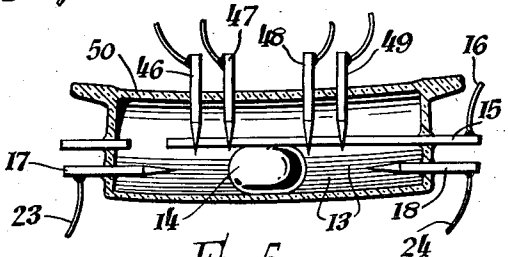


Fig. 5.

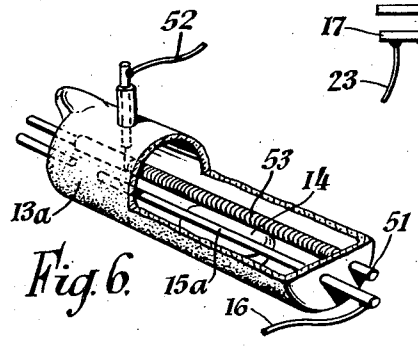


Fig. 6.

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CONTROL SWITCHES

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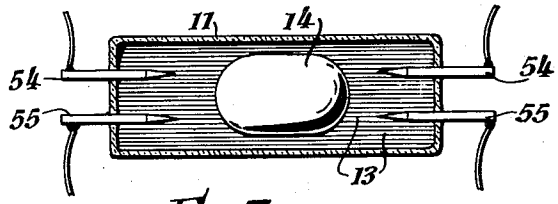



Fig. 7.

Fig. 8.

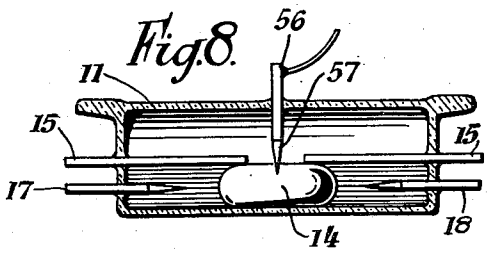
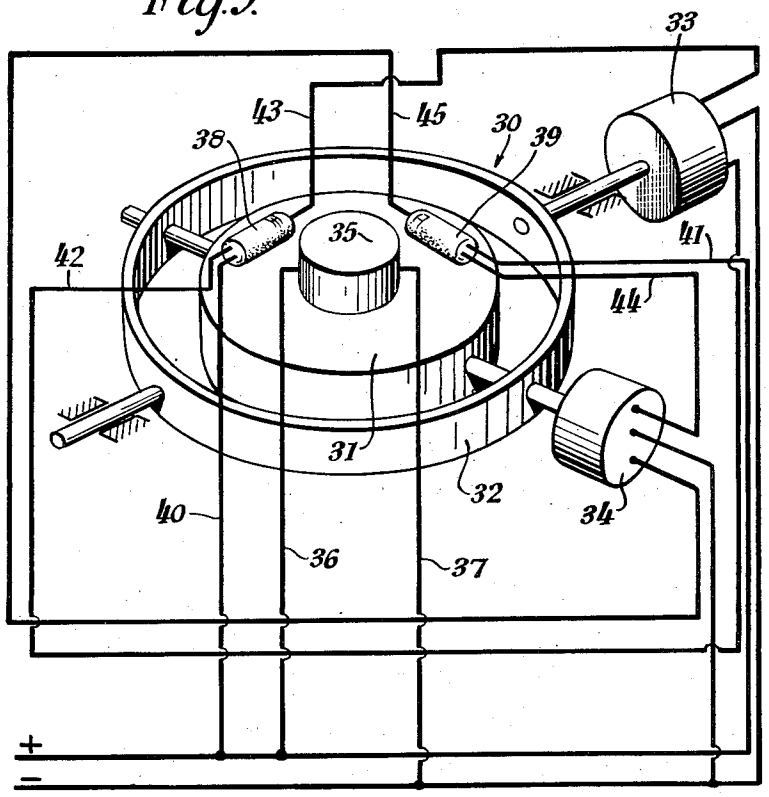



Fig. 9.

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# CONTROL SWITCHES

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Claims priority, application Great Britain July 17, 1953

3 Claims. (Cl. 200—152)

This invention relates to control swiitches for the making and/or breaking of electrical circuits.

The invention relates in particular to the so-called "mercury type" control switches in which an electrical conductive substance in fluid form, such as mercury, is contained in a sealed tube under vacuum or other desired conditions such as an inert gas. Two or more electrodes projecting into the tube are usually provided and the movement of the mercury is used to control an electric circuit by the completing or breaking of electrical continuity between the electrodes.

Control switches of this type are most efficient in operation and have widespread industrial applications. Where the switches are operated by tilting (usually about a transverse axis) it has been found however, that their sensitivity is rather less than five degrees and is frequently in the region of ten degrees. This lack of extreme sensitivity does not affect the normal industrial application of the switches as the tilting movement is usually greatly in excess of ten degrees. The applicants have realised however, that the switches could be more generally used on specialised apparatus if the sensitiviity of the switches could be increased. It is an important object of the invention therefore, to provide an improved control switch of the mercury type which is extremely sensitive even to very small tilting movements of the tube.

The efforts of the applicants to produce a more sensitive switch has now led to the use of less mercury than is usual in the tube of the switch. It has now been found that such an arrangement has a disadvantage in that the reduced mass of the mercury may cause an occasional failure of the mercury to make a good electrical connection with the electrodes. It is therefore a further object of the invention to provide a control switch of the mercury type having improved electrodes by which this disadvantage is substantially overcome.

A recent important industrial application of mercury switches is the control of electrically operated gyroscopes. It has been suggested that mercury level switches may be mounted on each gimbal of the gyro so that any tendency of the gyro axis to wander will tilt the corresponding switch to complete an electrical circuit operating the torque motors or other erection system of the gyro so that the wander of the gyro is counteracted.

Owing to the above mentioned disadvantages the results obtained have not been satisfactory, as known switches are not sufficiently sensitive. It is, therefore, a further object of the invention to provide a mercury type switch suitable for gyro control and sensitive to a wander movement of the gyro of a small fraction of a degree so that any tendency of the gyro axis to wander is immediately counteracted by the erection system.

It is of course well known to use gyroscopic units for the stabilising of ships, gun platforms on tanks and other land vehicles, and the present invention is most suitable for use with the gyros of such units.

The application of the invention to the gyroscopic units of aircraft has however, presented further difficulties



in that the use of mercury renders the units inoperative at temperatures below that at which mercury solidifies, i. e. about —39° C. At operational heights specified for most military aircraft this temperature is frequently exceeded and a still further object of the invention is therefore to provide a sensitive mercury level switch operative below the normal melting point of mercury and preferably to a temperature of approximately —60° C.

According to the present invention there is provided a control switch comprising a sealed envelope, two or more electrodes projecting therein, and an electrical conductive substance in fluid form in said envelope and movable to complete or break electrical continuity between the electrodes, wherein the envelope is formed with a matte or non-shiny track on its inner surface for the electrical conductive substance. Preferably the tube is roughened or ground and this may be obtained by the longitudinal rubbing of the surface of the tube by a diamond file during manufacture. It is believed that the minute longitudinal grooves or scratches so produced assist the smooth and even running of the mercury.

According to a further aspect of the invention there is provided a control switch comprising a sealed envelope, two or more electrodes projecting therein, and an electrical conductive substance in liquid form in said envelope and movable to complete or break electrical continuity between the electrodes, wherein the electrical conductive liquid is mercury and a substance amalgamated therewith whereby the melting point of the amalgam is lower than that of pure mercury.

One such substance is the element thallium and a preferred liquid includes 8% thallium amalgamated with mercury which has been triple distilled under vacuum.

Preferably the electrodes projecting into the envelope are formed with pointed contact portions to give a good electrical connection with the electrical conductive material. The electrodes are preferably of tungsten and the pointed ends are conveniently formed by grinding or by an electrolytic process in which the ends are gradually eaten away.

In one construction of a control switch according to the invention the envelope is provided with a rod electrode extending substantially along its length and there is an electrode at each end of the switch. If desired one or more additional electrodes may be positioned along the length of the rod electrode.

In a second construction, the envelope is provided with a pair of electrodes at each of its ends.

In a third construction, the envelope has a pair of spaced rods extending along its length, one of the rods being an electrode, and the other being formed of an insulating material and having a resistance wound thereon.

The envelope may be a straight or curved glass tube.

The control switches may be used for the control of gyroscopic units and the invention particularly provides an artificial horizon having two control switches, one responsive to movement of the unit in the pitching plane and the other to movement of the unit in the rolling plane. Preferably the control switches are connected to the corresponding torque motors of the erection system.

In order that the invention may be fully understood, some preferred embodiments will now be described by way of example with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a perspective view of a typical control switch according to the invention;

Figure 2 is a similar view partly in section to show the matte or non-shiny track on the inner surface of the tube;

Figure 3 is a section along the length of the tube;

Figure 4 is a similar section of a slightly different embodiment in which the tube is curved;

Figure 5 is a similar section of a further embodiment;

Figure 6 is a sectional perspective view of a further embodiment incorporating an internal resistance;

Figure 7 is a longitudinal section of a further embodiment;

Figure 8 is a similar section of a further embodiment; and

Figure 9 is a control system having control switches according to the invention for the erection system of an artificial horizon.

Referring now to Figures 1 to 4 of the drawings there is shown a control switch **10** comprising a glass tube **11** about an inch long and a quarter of an inch in diameter. The tube **11** is preferably straight in its longitudinal direction as shown in Figures 1 to 3, but if desired, it may be curved as shown in Figure 4 to suit various requirements regarding sensitivity and range of angular movement.

During manufacture the tube **11** is roughened or ground throughout its length on one half of its inner surface **12**. This renders the lower half of the tube opaque as shown at **13***a* in Figure 1. This roughened surface **12** forms a running surface for an electrical conductive liquid **14** (to be hereinafter described) and is formed during the manufacture of the switch by means of a diamond file which is rubbed upon the internal surface of the tube **11**. The roughened surface **12** includes minute longitudinal scratches **13** and it is believed that these greatly assist in the production of the surface which will ensure the smooth and even running of the liquid **14**.

The electrical conductive liquid **14** comprises an amalgam of mercury and thallium. The amount of thallium is preferably about 8% and the mercury is triple distilled under vacuum. The amalgam so formed is fluid at normal temperatures and solidifies at about —58° C. which is well below that for pure mercury (about —39° C.) and well below the operational requirements of most military and civil equipment.

The desired quantity of amalgam **14** is inserted in the tube **11** and the tube is then evacuated and sealed, great care being taken that no contact is made with the air by the amalgam.

Prior to this step various electrodes are sealed into the walls of the tube **11**.

In its most simple form the tube **11** is provided with a rod electrode **15** extending the length or substantially the length of the tube **11** approximately along its longitudinal axis. This electrode **15** is conveniently connected at its outer end to a source of electrical energy by a wire **16**.

Below the rod electrode **15** (i. e. on that side of the rod **15** adjacent the roughened wall **12** of the tube), there is mounted a pair of electrodes **17, 18**, parallel with the rod electrode **15** and extending into the tube **11** one from each end **19, 20** respectively. The electrodes **15, 17** and **18** are made from tungsten and the two lower electrodes **17** and **18** have contact portions **21, 22** in the form of sharply pointed ends. Such contacts **21, 22** ensure a good connection with the moving mass of amalgam **14** and are produced by treatment in an electrolytic bath or by grinding.

The amount of amalgam **14** in the tube **11** is such that with the tube level (Figure 3) the mass of amalgam **14** is spaced from the two pointed electrodes **17, 18** but is in contact with the rod electrode **15**.

The two pointed electrodes **17, 18** are connected by wires **23, 24**, into various control circuits as desired and in operation any tilt of the tube **11** in one direction or the other will cause the mass of amalgam **14** to run into one of the pointed electrodes **17, 18** and so complete the corresponding circuit. The amalgam **14** is of course, at all times in running contact with the rod electrode **15**.

The preferred use of the switch is for the control of gyroscopic units, such as directional gyros, and artificial horizons on aircraft.

One such application of the invention is shown in Figure 9 in which the control switches control the operation of the erection system of an artificial horizon.

The artificial horizon includes a vertical gyro mounted in a support **30** which includes an inner gimbal **31** and an outer gimbal **32**. An erector system precesses the gyroscope axis to the vertical and includes a pitch precessing motor **33** with its axis extending fore and aft of the craft on which the gyroscope is mounted, that is on the gyroscope's bank axis, and a bank precessing motor **34** with its axis extending transversely of the craft, that is on the gyroscope's pitch axis. The gyroscope is housed within a casing **35** and is connected with an electrical supply by leads **36, 37**.

Two control switches **38, 39** are mounted on the inner gimbal **31** and are connected to the electrical supply by leads **40, 41** respectively. The leads **40, 41** are connected to the rod electrodes **15** of the switches. The electrodes **17, 18** of the switch **38** are connected by leads **42, 43** to the motor **33** so that the motor **33** will be energised in one or the other direction of rotation depending upon the tilting of switch **38**. The switch **38** is mounted on the gimbal **31** along the fore and aft of the craft and any deviation of the gyro from the vertical in the fore and aft direction will therefore operate the switch **38** to close the circuit to the motor **33**. The motor **33** applies the correct couple to the gyro axis to cause it to precess and return to its vertical position. Similarly the electrodes **17, 18** of the switch **39** are connected by the leads **44, 45** to the torque motor **34** so that the motor will be energised by the switch upon a deviation of the gyro from the vertical in the transverse direction.

The switches **38, 39** will therefore operate to correct any tendency of the gyroscope axis to wander from the true vertical due to the effect of the earth's rotation, friction etc. The switches are extremely sensitive and a tilting movement of one hundredth of a degree or less will operate the switch. If desired the switch **39** can be attached to the outer gimbal **32**.

During turns, the switch **39** mounted parallel with the pitch axis of the aircraft is subject to the action of centrifugal force and thus may operate to give errors in the control of the gyro. These errors may be avoided by means of the known pitch-bank systems of erection switching in which control of the torque motor **33** operating on the roll axis is transferred to the pitch axis control system.

The simple control switches as described above may in some circumstances suffer the disadvantage of hunting of the gyro under control.

This defect can be corrected by providing the tube **11** as shown in Figure 5 which has a plurality, for example four, additional pointed electrodes **46, 47, 48, 49** extending downwardly from the upper surface **50** of the tube at the side of the rod electrode **15** and to a point just below it. The additional pointed electrodes **46** to **49** are spaced along the length of the tube and are arranged so that movement of the amalgam along the tube in one direction progressively brings the series of electrodes into electrical connection one after the other with the rod electrode **15**. It will be appreciated that the electrodes can be connected in circuits with the same torque motor, each circuit including a resistance of different value so that successive electrodes from the centre of the tube will produce currents of decreasing value for loading the motor to produce a more accurate and gradual control.

It is preferred to mount the multiple electrode switch of Figure 5 and its resistances in a panel so that the device can be fitted as a unit. A cover plate, for example of plastic, can be fitted to the panel to prevent damage and the entry of dirt. In certain instances such as the control of automatic pilots, the panels are provided with a series of recesses adapted to take two switches or more

at right angles to each other together with their resistances.

In a further modification shown in Figure 6 the resistances are provided internally of the tube. In this form of the invention the tube **11** has two rods **15***a*, **51** extending along its length parallel to each other, one of the rods being the same as the rod electrode **15** referred to above. The other rod **51**, which may be of any suitable insulating material is connected with the torque motors by the lead **52** and is provided with a wound resistance **53** thereon. It will be appreciated, therefore, that movement of the amalgam **14** will have the effect of connecting the rod electrode in circuit with the torque motor through a varying resistance.

In a further modification shown in Figure 7 a tube **11** can be produced without the rod electrode. In this arrangement the tube is provided with a pair of pointed electrodes **54**, **55** at each end, one electrode say **54**, of each pair being connected to the source of electrical energy.

A still further form of switch shown in Figure 8 provides means for the insertion of a higher current into a completed circuit as is required, for example, for the rapid erection of a gyro under certain operational requirements.

The gyro is conveniently provided with a "rapid erection button" at the side of the unit and depression of this button is arranged to complete a circuit which connects a "rapid erection" electrode **56** in the switch tube **11** with an electrical supply source of greater voltage or current.

The "rapid erection" electrode is pointed at **57** as shown and depends from the upper surface of the tube at approximately its mid-point. If desired the rod electrode **15** (if fitted) can be split at this point but the electrodes must of course all be positioned so that contact can be made with both the "rapid erection" electrode **56** and one of the circuit electrodes **17**, **18** by the amalgam **14** during at least a certain range of tilt of the tube.

The control switch described above have of course industrial applications too numerous to mention but it will be appreciated that their use is invaluable where an extremely sensitive and accurate electrical control is required. Due to the particular amalgam used the control switches are not subject to errors due to temperature variation and they are in fact fully and accurately operational in a temperature range starting at the abnormally low value of −58° C.



We claim:

1. A control switch comprising a tubular glass envelope, said envelope sealed at each end and under vacuum, a plurality of sharply pointed electrodes projecting into said envelope, an electrical conductive substance in fluid form in said envelope and movable to complete or break the electrical continuity between the electrodes, and a plurality of longitudinal scratches on the lower half of the inner surface of said glass envelope extending the length thereof to form a track for said conductive substance whereby the smooth and even running of the electrical substance is insured.

2. A control switch comprising a tubular glass envelope, said envelope sealed at both ends and under vacuum, a plurality of electrodes projecting into said envelope, at least one electrode being sharply pointed, at least one electrode being of rod-like form, an electrical conductive substance in fluid form in said envelope and movable to complete or break electrical continuity between said rod-like and sharply pointed electrodes, and a plurality of minute longitudinal scratches on the lower half of the inner surface of said glass envelope extending the length thereof to form a track for said conductive substance.

3. A control switch comprising a tubular glass envelope, said envelope being sealed at both ends and under vacuum, a pair of spaced rods extending the length of the envelope, one of the rods being an electrode the other rod being formed of insulating material and having a resistance wound thereon, an electrical conductive substance in fluid form in said envelope and movable to complete or break electrical continuity between said electrode and wound resistance, and a plurality of minute longitudinal scratches on the lower half of the inner surface of said glass envelope extending the length thereof to form a track for said conductive substance.

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