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CIRCUIT CONTROL APPARATUS

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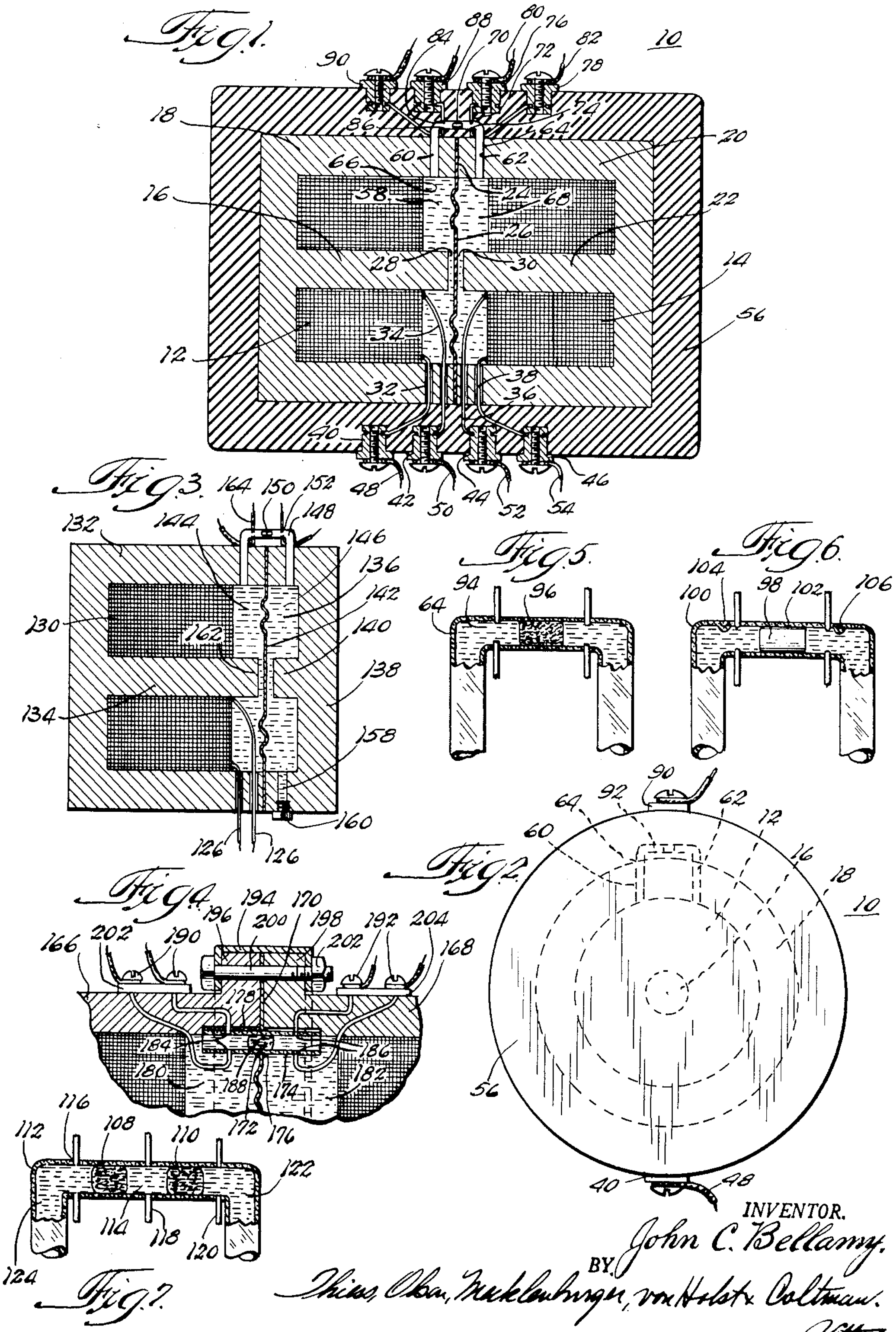

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CIRCUIT CONTROL APPARATUS

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This invention relates to circuit control apparatus, and more particularly to magnetically actuated circuit controlling relays.

It is an important object of this invention to provide improved apparatus for controlling the energization of various external electric circuits in response to the magnitude of a variable, such as an electric current or voltage.

Circuit control apparatus heretofore known as primarily relied upon the motion of one or more contacts, each contact being mounted on a cantilever beam to complete various electric circuits by engagement with a corresponding contact mounted in fixed relationship to a source of magnetic flux. Typically, the source of flux is an energized coil of wire wound on an iron core. The motion of the movable contact is produced either by attracting the contact mounting means constructed of a magnetic material or by the use of a magnetic armature attractable to the source of magnetic flux and adapted to move the various contact cantilevers through an insulating connecting structure. The contacts are generally exposed to the atmosphere and are thus subject to arcing and rapid deterioration in use. The cantilever type of mounting necessitates a relatively large relay structure and limits the speed with which the circuit control apparatus can be operated. Furthermore, such a cantilever type of relay has limited sensitivity, is generally not completely sealed from the atmosphere, requires accurate production control for satisfactory operation of the moving parts and consequently is comparatively expensive to construct.

Therefore, it is another object of this invention to provide improved circuit control apparatus having an increased useful life.

It is a further object of this invention to provide improved circuit control apparatus which is completely sealed and self-contained and has therein one or more sets of contacts which will not be subject to deterioration resulting from contact with the atmosphere and concomitant arcing.

It is another object of this invention to provide improved circuit control apparatus having increased sensitivity and actuating speed.

It is an additional object of this invention to produce a relay having increased speed and sensitivity through the use of a fluid system having a large actuating surface and a reduced path through which a confined fluid moves to actuate a circuit control means in said path.

It is still another object of this invention to produce an improved relay having fluid means to replace the mechanical levers heretofore known in the circuit control art.

It is another object of this invention to utilize a mercury contactor carried by an insulating fluid whereby contact resistance is greatly reduced and contact arcing and deterioration substantially eliminated.

Further and additional objects will become manifest from a consideration of this specification, the accompanying drawings, and the appended claims.

In one form of this invention a soft iron shell may be

provided having an integral central iron core. A magnetic diaphragm is associated with said iron shell having its central portion in fixed spaced relationship from the end of said iron core. A confined fluid is retained within said shell by said diaphragm, and by the attraction of the diaphragm under the influence of a magnetic flux the diaphragm, and consequently the fluid, is set in motion and actuates various external circuits by the effect of said fluid motion upon associated contact means.

More particularly, an external fluid path is provided which bypasses the diaphragm and interconnects fluid chambers positioned on either side of the diaphragm. A plurality of electrical contacts are mounted along this fluid path, and a conducting slug such as a quantity of mercury is suspended in the external fluid path whereby any motion of the diaphragm will produce a fluid displacement from the chamber on one side of the diaphragm to the associated chamber on the other side of the diaphragm and will result in motion of the mercury slug along the external path connecting said chambers. The motion of this mercury slug along the external path will open or complete any desired external circuits by the proper orientation of contact means engageable by the mercury slug positioned along the path. Thus, a contact is provided which utilizes mercury as the contacting element producing a circuit closure of very low contact resistance and as the mercury slug is completely surrounded by a fluid, preferably a fluid of high dielectric strength, any arcing or current leakage is minimized.

For a more complete understanding of this invention reference should now be made to the accompanying drawing, wherein

Figure 1 is an illustration in section of one embodiment of this invention adapted for differential actuation;

Fig. 2 is an end view of the embodiment of Fig. 1;

Fig. 3 illustrates in section a second embodiment of this invention using a single actuating coil;

Fig. 4 is a partial view in section of a third embodiment of this invention illustrating a modified external fluid path;

Fig. 5 illustrates one possible contact arrangement which may be employed with this invention;

Fig. 6 illustrates a second possible contact arrangement utilizing a solid metallic slug; and

Fig. 7 illustrates another possible contact configuration which may be employed with this invention.

The drawing is more or less diagrammatic in form to better illustrate the application of the principles involved.

Referring now to the drawings and more particularly to Figs. 1 and 2, a completely sealed relay **10** is illustrated which is adapted for differential operation, that is, the relay has a pair of oppositely mounted actuating coils **12** and **14** which may be selectively energized to complete independent electrical circuits. Such a coil configuration may also be utilized to compare the relative magnitudes of two independent eletcrical signals whereby the difference of the two magnitudes will determine the position of the associated contactor, and consequently, the completion of the associated external circuits.

The coil **12** is mounted on an iron core **16** which is centrally located in and formed integrally with a cylindrical iron shell **18**. The shell **18** and integral core **16** may be formed of any magnetic material and may be formed in a single unit or be of a laminated construction. The advantages of soft iron or other magnetic material having low retentivity are manifest to one aware of magnetic phenomena, as are the advantages of using a laminated core structure to reduce eddy current losses.

A second cylindrical shell **20** is provided to receive the associated coil **14**. An iron core **22** is integrally formed centrally within the cylindrical shell **20**, and the coil **14** is mounted thereon. The shell **20** and core **22** should have magnetic characteristics substantially the same as those of the corresponding shell 18 and core 16.

As shown in Fig. 1, the shells 18 and 22 are assembled with their free outer edges clamped together to retain the peripheral surface 24 of a diaphragm 26 therebetween. The length of cores 16 and 22 should be somewhat less than the over-all length of the cylindrical walls of shells 18 and 20, whereby an air gap 28 will exist between the end of core 16 and the diaphragm 26, and a similar air gap 30 will exist between the end of core 22 and the central portion of the diaphragm 26. It may be desirable to insert non-magnetic spacers secured to the poles of cores 16 and 22 to partially fill the gaps 28 and 30. By such spacers, limits of travel of the diaphragm are established whereby overload voltages may be applied to the windings 12 and 14 without producing excessive diaphragm motion.

The lead-in conductors necessary for energization of coils 12 and 14 extend from the coils through apertures in shells 18 and 20 and terminate at metallic terminal bushings 40, 42, 44, and 46. The terminals 40 and 42 are connected to a source of variable voltage through the conductors 48 and 50 and will provide the energizing current through conductors 32 and 34 to the actuating coil 12. In a like manner, conductors 52 and 54, here partially shown, are connected from the terminal bushings 44 and 46 to a second source of variable voltage which will provide an actuating current through conductors 36 and 38 to the opposed actuating coil 14. The terminal bushings 40—46 are integrally molded in an insulating housing 56 whereby a completely sealed unit is formed which will not be subject to leakage or admission of atmosphere which would result in deterioration of the electrical components contained therein.

A sealed cavity is formed within the two shells 18 and 20 mounted in abutting relationship. This cavity is partially filled by coils 12 and 14, and the remainder of the cavity is filled with a fluid medium 58 which may be any appropriate material having a high dielectric strength and high dielectric coefficient. Fluids suggested for this use are transformer oil or freon, though it should be clear that many available fluids would be satisfactory. An aperture 60 is formed in the shell 18, and a corresponding aperture 62 is formed in the shell 20. These apertures are lined and interconnected by an insulating tube or tubes 64 which provides an external fluid path connecting the isolated chambers 66 and 68 of the fluid cavity which are otherwise isolated by the diaphragm 26. In manufacture, it is desirable to completely fill the chambers 66 and 68 and the external fluid path within tube 64. Thereby air and moisture are completely excluded from the sealed unit, and deterioration and contact arcing is substantially eliminated. Integrally fused into the tube 64 are a plurality of electrical contacts 72, 74, 84 and 86. As shown in this embodiment, two sets of oppositely disposed contacts are shown whereby two normally open circuits are provided. A metallic slug 70 is centrally disposed within the external tube 64 and will remain in this central position whenever the coils 12 and 14 are deenergized or energized equally.

If one of the coils 12 or 14 is independently energized, the diaphragm 26 is attracted to the pole portion of the associated core 16 or 22. This will produce a differential pressure within the chambers 66 and 68 and will thus produce fluid motion through the external path 64. As the slug 70 substantially fills the external path, any motion of the fluid in this path will produce lateral motion of the slug. Therefore, if the coil 12 is energized the diaphragm 26 is attracted to the core 16, producing an increase in pressure in the chamber 66 and a reduction in the pressure within the chamber 68. This will cause fluid flow through the external path from chamber 66 to chamber 68 and will thus cause metallic slug 70 to move to the right in Fig. 1 and complete a circuit through the spaced contacts 72 and 74.

The contact 72 is connected by a flexible conductor to a terminal bushing 76, and contact 74 is connected by a flexible conductor to the terminal bushing 78. A pair of conductors 80 and 82, here partially shown, will be connected from the terminals 76 and 78 to any associated apparatus which it is desired to control in response to variations in the relative magnitudes of the currents in coils 12 and 14. A second pair of contacts 84 and 86 is provided and integrally fused in the tube 64 and disposed to the left of center of the path 64, as shown in Fig. 1. These contacts will be completed by motion of slug 70 to the left in response to an increased pressure in chamber 68 and a decreased pressure in chamber 66 normally resulting from a current flowing in coil 14. The contact 84 is connected by a flexible conductor to a terminal bushing 88 and the contact 86 is connected to a similar terminal bushing 90, thus providing easily accessible connecting points for external apparatus to be controlled by the signals impressed upon this device as described above. Terminals 76, 78, 88 and 90 are molded in housing 58 to provide a completely sealed enclosure.

The orientation of the various elements of this apparatus is clearly shown in the end view of Fig. 2. The general appearance of this apparatus in an end view is that of a plurality of concentric circular structures. As shown in dotted lines, the structure consists of the circular core 16 on which a coil 12 is wound which is in turn surrounded by the iron shell 18. This entire unit is then molded into an insulating housing 56. The housing 56 may be made of any conventional material capable of formation under heat or pressure, such as a phenolic polyethylene, or like circulating material. The external fluid path 64 is shown in Fig. 2 having the two vertical passageways 60 and 62 displaced about the circumference of shell 18. The exact position of these passageways is not important to this invention but should be chosen to provide a substantial horizontal path 92 whereby the desired contacts and movable slugs may be readily oriented therein. Thus a relatively long path 92 may be provided by offsetting the two passageways 60 and 62 a substantial distance from one another about the circumference of the shells 18 and 20.

While the terminal bushings 90 are shown in the embodiments of Figs. 1 and 2 aligned along an element parallel to the axis of the cylindrical cores, it should be clear that this orientation of terminals is merely expedient in the drawing to clearly illustrate the manner in which the various terminals and conductors are associated, and in manufacture it may be found desirable to orient the various terminals about the circumference of the housing 56.

The particular contact orientation utilized in the embodiment of Fig. 1 is illustrated in Fig. 5. There it can be seen that the external path 64 is filled with a fluid 94 and has centrally disposed therein a slug of mercury 96. The dimensions of the tube 64 should be so chosen that an appropriate amount of mercury will be contained within the passageway and will completely close a diametrical section of the tube 64 whereby no fluid will be allowed to pass from one side of the mercury slug 96 to the other. Thus by choosing the tube 64 having a dimension corresponding to the capillary dimensions which are known for mercury, the position of the mercury slug 96 will be permanently insured unless leakage from one chamber to the other within the fluid cavity develops. The tube 64 may be formed of any insulating material but is preferably formed of a material which has a relatively low adhesion with mercury as compared with the cohesion of mercury itself whereby the tube surfaces are not wetted. Glass is especially well adapted for this purpose, as the contact angle which mercury forms with respect to glass is an angle of 132°. By choosing material such as glass, the adhesion of the mercury causes the formation of a globule much like that shown in Fig. 5, which will fill the entire cross-sectional dimension of the tube 64 and will not spread or flatten along the lower surface of the glass tube sufficiently to provide a fluid bypass above the upper surface of the globule. In addition to choosing a material having a high surface tension with respect to mercury for the tube **64**, the amount of mercury forming slug **96** should completely fill the cross section of tube **64** in a suitable manner as shown in the drawing.

As shown in Fig. 6, a solid slug **98** may also be utilized in the tube **100**, and in this embodiment a tube of any diameter may be used, and a slug **98** is provided having a diameter slightly less than that of the tube whereby the slug will be free to move within the tube and will consequently freely pass a small quantity of fluid through the small gap **102**.

Because of this small fluid passage it is considered desirable in this embodiment to provide a pair of stops **104** and **106** at each end of the normal slug travel whereby the slug may be repositioned whenever necessary to insure proper positioning of the slug within the tube **100** at all times. If, as a result of mechanical jarring or vibration, the slug **98** becomes disposed from its normal position, it may readily be repositioned by merely energizing one of the actuating coils as described with respect to Fig. 1, whereby the slug will be forced to one of its extreme positions and abut against either stop **104** or **106**. In this position any excess fluid which has been displaced from the appropriate side of the diaphragm will be forced through the cap **102**, and by this expedient the slug **98** will be repositioned with the proper amount of fluid on each side thereof whereby normal operation will once again be possible. The contacts should extend beyond the surface of tube **100** a sufficient distance to insure positive contact and are preferably of a flexible character.

Fig. 7 illustrates another possible contact configuration in which two mercury slugs **108** and **110** are disposed within a glass tube **112** and are spaced a predetermined distance apart with a quantity of fluid **114** disposed therebetween. The remainder of the tube **112** and the associated fluid chambers are filled with a similar oil, and in this embodiment three pairs of associated contacts **116**, **118**, and **120** are fused into the glass tube **112** in spaced relationship, whereby two normally open circuits between contacts **116** and **118** will normally be completed when the slugs **108** and **110** are forced to the left in Fig. 7 as a result of an increased pressure in the fluid **122** to the right of slug **110**. Likewise, the two normally open circuits between contacts **118** and contacts **120** will be completed when the associated coil apparatus is energized to create an increase in pressure in the fluid **124** to the left of slug **108** in tube **112**. This will cause the slug **108** to align with contacts **118** and complete a circuit therethrough and the slug **110** to align with contacts **120**, thereby completing a circuit through said contacts.

While this particular orientation of contacts and slugs has been shown, it is intended to be merely exemplary of the unlimited number of combinations which will be immediately available to one skilled in the relay art. In various switching operations, especially telephone switching and the like, complex combinations of normally open and normally closed circuits are arranged to be actuated by a single coil or pair of coils. Any of these contact combinations may readily be constructed within the tube **12** by the proper orientation of contacts along the length of the tube and the appropriate positioning of mercury slugs within the tube. As an example of this, by merely shifting the position of slug **108** or slug **110**, or both, a small increment to the right in Fig. 7, it will be immediately apparent that either contacts **118** or **120** or both become a pair of normally closed contacts which will be opened upon a change in pressure in the fluid **122**.

The embodiment shown in Fig. 3 is similar to that shown in Fig. 1 but is adapted for operation by a single variable voltage applied to the conductors **126** and **128**. In this embodiment a coil **130** is mounted within a cylindrical shell **132** and has a central core **134** extending therethrough. The core **134** and shell **132** may be composed of a magnetic, low retentivity material as described above. The fluid chamber **136** is completed by providing a cover **138** which will have a cylindrical shell shape and also have a short core member **140** extending from the central portion thereof. This shell may be constructed of a magnetic material also, thus providing a relatively short magnetic gap between the poles of cores **134** and **140**, or the shell **138** may be formed of a non-magnetic material, in which case the magnetic circuit associated with the coil **130** will be completed through the core **134**, the shell **132**, and the diaphragm **142** secured in place against the free edge of the shell **132**.

As described with respect to Fig. 1, the diaphragm **142** defines two independent fluid chambers **144** and **146** which are connected only by an external tube **148** in which a conducting slug **150** is suspended. The slug **150** is adapted to complete a circuit through contacts **152** when the coil **130** is energized creating an increased pressure in the fluid chamber **144**.

Various manners of assembly will be immediately apparent, but one that is herein shown provides for the securing of the diaphragm **142** to the shell **132** and the completion of the fluid cavity by securing shell **138** to the other peripheral surface of diaphragm **142**. These connections may be made by welding, brazing or the like. The fluid cavity **136** is then filled through aperture **158**. Aperture **158** is threaded to receive a correspondingly threaded cap **160**.

The apparatus described above and shown in Figs. 1 and 3 may be acuated by either A. C. or D. C. voltages applied to the coils, relying only upon the inertia of the system in A. C. operation to prevent intermittent closure of the associated contacts. If desired, a polarized D. C. relay may readily be constructed from the teaching of Fig. 3. By substituting for the low retentivity core **144** and shell **132** a core and shell having high magnetic retentivity properties which is permanently magnetized, the diaphragm will be normally attracted to the core face **162**. Thus, depending upon the polarity of magnetization of the core and shell and the polarity of the current in the coil **130**, the magnetic fields resulting therefrom will either be oriented in aiding or opposing relationship. Thus by positioning the slug **150** of Fig. 3 in the central position shown when zero current is flowing in the coil **130**, a positive current flowing therein will cause a motion of the diaphragm **142** in one direction and a negative current in coil **130** will cause the diaphragm **142** to move in the opposite direction.

Thus while a positive current in coil **130** might cause an aiding flux to be created thus causing completion of a circuit through contacts **152** by positioning the slug **150** therebetween, a negative current would cause an opposing flux and consequently opposite motion of the diaphragm **142** and would thus complete a circuit through contacts **164** by positioning slug **150** between said contacts. It will be clear that the relay shown in Fig. 3 or the polarized relay just described may be encased in a housing identical to that shown in Fig. 1.

Another embodiment of this invention is shown in Fig. 4 in which the external fluid path is somewhat simplified. In the embodiment shown in Fig. 4, a portion of a pair of abutting shells **166** and **168** are shown clamping the peripheral edge **170** of a flexible diaphragm therebweteen. However, in this embodiment the diaphragm **170** has an aperture **172** therein through which a tube **174**, such as the glass tube described, is inserted. The tube **174** will be sealed to the flexible diaphragm by any conventional means such as a cemented fillet **176** and is secured to one of the shell members **166** by a similar cement joint **178**. Thus the only fluid access between the left-hand chamber **180** and the right-hand chamber **182** is through the glass tube **174**. In this embodiment, as in those above described, a pair of contacts **184** is mounted in the left-hand portion of tube **174**, and a similar pair of contacts **186** is mounted in the right-hand portion of glass tube 174. A mercury slug 188 is suspended centrally in the tube and adapted for lateral motion within the tube whenever a differential pressure exists within the fluid chambers 180 and 182. Flexible conductors extends from the contacts 184 and 186 to terminals 190 and 192 mounted on insulated spacers 204 and 206 on the external surface of the shells 166 and 168. This entire unit is then shown assembled by a split ring 194 which is slipped over the assembly of flange 196 extending outwardly from the edge of shell 166, the periphery 170 of the diaphragm and flange 198 extending outwardly from the edge of shell 168. The split ring 194 is secured in place by a plurality of bolts 200 extending through the split ring, flanges, and the periphery of the diaphragm. Only one such bolt is here shown, although it should be clear that a plurality may be desired for proper clamping. Each of the bolts 200 is secured in place by the corresponding nut 202.

While various embodiments of this invention are herein shown and described, it will be immediately clear that a plurality of combinations of coils, cores, mounting means, contact orientation, and casings will be immediately obvious from the teaching of the embodiments herein specifically described, as well as the various ramifications of these embodiments which are taught by this invention and are believed manifest in this description.

For example, the fluid passageway herein shown has a glass tube which may be positioned anywhere along the surface of the diaphragm, although it is herein shown in Fig. 4 as positioned only against the shell 166. Furthermore, it would be possible to mount the external path completely without the housing, whereby the position of the slug could be observed through a transparent tube, facilitating maintenance and inspection.

As described above, it would also be possible to conceive any combination of normally open or normally closed contact configurations or transfer contacts or combined operation of a plurality of contacts by proper spacing of the mercury slugs with respect to various contact positions.

Without further elaboration, the foregoing will so fully explain the character of my invention that others may, by applying current knowledge, readily adapt the same for use under varying conditions of service, while retaining certain features which may properly be said to constitute the essential items of novelty involved, which items are intended to be defined and secured to me by the following claims.

I claim:

1. A control device for electric circuits comprising a variable source of magnetic flux, a sealed housing, a diaphragm of magnetic material mounted in spaced relationship to said source and dividing said sealed housing into two substantially isolated chambers, a communicating passageway between said chambers, an electrically nonconducting fluid medium substantially filling said chambers and communicating passageway, and contact means having at least one movable element actuated by the differential fluid pressure created in said passageway between said chambers by the motion of said diaphragm resulting from the forces of the flux source thereon.

2. A control device for electric circuits comprising a variable source of magnetic flux, a sealed housing, a diaphragm of magnetic material mounted in spaced relationship to said source and dividing said sealed housing into two substantially isolated chambers, an electrically nonconducting fluid medium substantially filling said chambers, closed fluid path connecting said chambers, and contact means having at least one movable element actuated by the motion of a portion of said fluid through said path resulting from a differential fluid pressure created between said chambers by the motion of said diaphragm resulting from the magnetic forces of the flux source acting thereon.

3. A control device for electric circuits comprising a variable source of magnetic flux, a sealed housing, a diaphragm of magnetic material mounted in spaced relationship to said source and dividing said sealed housing into two substantially isolated chambers, an electrically nonconducting fluid medium substantially filling said chambers, a closed fluid path connecting said chambers, and contact means mounted in spaced relationship in said path having at least one movable element whereby said contact means is actuated by motion of fluid through said path resulting from a differential fluid pressure created between said chambers by the motion of said diaphragm resulting from the magnetic forces of the flux source acting thereon.

4. A control device for electric circuits comprising a variable source of magnetic flux, a sealed housing, a diaphragm of magnetic material mounted in spaced relationship to said source and dividing said sealed housing into two substantially isolated chambers, a fluid medium substantially filling said chambers, a closed fluid path connecting said chambers, an insert of conducting material movably positioned in said path, and contact means mounted in spaced relationship in said path whereby said contact means completes such an electric circuit through said conducting insert when the position of said diaphragm is altered by said flux source to cause a displacement of said fluid medium along the path.

5. A control device for electric circuits comprising a cylindrical housing of magnetic, low retentivity material, a core of magnetic, low retentivity material coaxial and formed integrally with said cylindrical housing, a coil of conducting material wound on said core, a substantially circular flexible diaphragm of a magnetic material secured to the periphery of said cylindrical housing and having its central portion in spaced relationship to said core to divide the housing into two substantially isolated chambers, a fluid medium having immiscible conducting and nonconducting portions substantially filling said housing, means defining a fluid path connected to said housing to interconnect said chambers, and contact means mounted in spaced relationship in said path whereby said contact means is actuated by motion of fluid between said chambers in said path resulting from a fluid pressure created within said housing by the motion of said diaphragm in response to energization of said coil.

6. A control device for electric circuits comprising a cylindrical housing of magnetic, low retentivity material, a core of magnetic, low rententivity material coaxial and formed integrally with said cylindrical housing, a coil of conducting material wound on said core and filling a portion of said housing, a substantially circular flexible diaphragm of a magnetic material secured to the periphery of said cylindrical housing dividing the space within said housing into two substantially isolated chambers and having its central portion in spaced relationship with said core, a fluid medium substantially filling said chambers, a closed fluid path connecting said chambers, a movable conducting insert in said path, and contact means mounted in spaced relationship within said path whereby a circuit is completed through said conducting insert when aligned with said contact means.

7. A control device for electric circuits comprising a variable source of magnetic flux, a sealed housing, a diaphragm of magnetic material mounted in spaced relationship to said source and dividing said sealed housing into two substantially isolated chambers, a non-conducting fluid medium substantially filling said chambers, a closed fluid path connecting said chambers, said fluid path having transverse dimensions of capillary magnitude, a quantity of conducting fluid in said fluid path, and contact means mounted in spaced relationship in said path whereby said contact means completes such an electric circuit through said conducting fluid when the position of said diaphragm is altered by said flux source to cause a displacement of said fluid medium along the said path.

8. A control device for electrical circuits differentially operable from two variable sources of control, said device comprising two variable sources of magnetic flux, a sealed housing, a diaphragm of magnetic material mounted in spaced relationship between said sources of flux and dividing said sealed housing into two substantially isolated chambers, a fluid medium substantially filling said chambers, a closed fluid path connecting said chambers, an insert of conducting material movably positioned in said path, and contact means mounted in spaced relationship in said path whereby said contact means completes such an electric circuit through said conducting insert when the position of said diaphragm is altered by said flux source to cause a displacement of said fluid medium along the path.

9. A control device for electric circuits differentially operable from two variable sources of voltage, said device comprising a cylindrical housing having a coaxial core formed integrally therein, said housing and core being of a magnetic, low retentivity material and said core being discontinuous at a point intermediate the ends of said housing, a pair of coils, one of said coils mounted on said core at each end of said cylindrical housing, a flexible diaphragm of a magnetic material sealed to said housing and having its central portion in spaced relationship within the discontinuity in said core, an electrically nonconducting fluid medium substantially filling said housing, a fluid path interconnecting the opposite sides of said diaphragm, and contact means mounted in spaced relationship in said path at least one element of which is movable whereby said contact means is actuated to complete such electric circuits by motion of fluid in said path resulting from the motion of said diaphragm in response to the differential energization of said coils.

10. A control device for electric circuits differentially operable from two variable sources of voltage, said device comprising a cylindrical housing having a coaxial core formed integrally therein, said housing and core being of a magnetic, low retentivity material and said core being discontinuous at a point intermediate the ends of said housing, a pair of coils, one of said coils mounted on said core at each end of said cylindrical housing, a flexible diaphragm of a magnetic material sealed to said housing and having its central portion in spaced relationship within the discontinuity in said core, an electrically nonconducting fluid medium substantially filling said housing, a fluid path interconnecting the opposite sides of said diaphragm, contact means mounted in spaced relationship in said path at least one element of which is movable whereby said contact means is actuated to complete such electric circuits by motion of fluid in said path resulting from the motion of said diaphragm in response to the differential energization of said coils, a sealed insulating casing completely enclosing said cylindrical housing and a plurality of terminals mounted on said casing and electrically connected to said contact means and said coils.

11. A control device for electric circuits comprising a cylindrical housing of magnetic material, a core of magnetic material coaxial and formed integrally with said cylindrical housing, a coil of conducting material wound on said core and filling a portion of said housing, a substantially circular flexible diaphragm of a magnetic material secured to the periphery of said cylindrical housing dividing the space within said housing into two substantially isolated chambers and having its central portion in spaced relationship with said core, said housing and coil being magnetized whereby the free end of said core has a predetermined residual polarity and the direction of motion of said diaphragm is determined by the direction of current flow in said coil, a fluid medium substantially filling said chambers, a movable conducting insert in said path, and contact means mounted in spaced relationship within said path whereby a circuit is com-

pleted through said conducting insert when aligned with said contact means.

12. A control device for electric circuits comprising a plurality of variable sources of magnetic flux, a sealed housing, a diaphragm of magnetic material mounted in spaced relationship to said sources and dividing said sealed housing into two substantially isolated chambers, an electrically nonconducting fluid medium substantially filling said chambers, a closed fluid path connecting said chambers, and contact means mounted in spaced relationship in said path at least one element of which is movable whereby said contact means is actuated by motion of fluid through said path resulting from a differential fluid pressure created between said chambers by the motion of said diaphragm resulting from the magnetic forces of the flux source acting thereon.

13. A control device for electric circuits comprising a variable source of magnetic flux, a sealed housing, an apertured diaphragm of magnetic material mounted in spaced relationship to said source and dividing said sealed housing into two substantially isolated chambers, an electrically non-conducting fluid medium substantially filling said chambers, an insulating tube in sealed engagement with said diaphragm and extending through the aperture therein to provide fluid communication between said chambers, and contact means mounted in said tube having at least one movable contact actuated by the motion of a portion of said fluid through said tube resulting from the motion of said diaphragm in response to changes in the magnitude of the magnetic flux.

14. A control device for electric circuits comprising a variable source of magnetic flux, a sealed housing, an apertured diaphragm of magnetic material mounted in spaced relationship to said source and dividing said sealed housing into two substantially isolated chambers, a nonconducting fluid medium substantially filling said chambers, an insulating tube in sealed engagement with said diaphragm and extending through the aperture therein to provide fluid communication between said chambers, a metallic insert movably positioned in said tube, and spaced contact means mounted in said tube actuated by the motion of said insert through said tube resulting from the motion of said diaphragm in response to changes in the magnitude of the magnetic flux.

15. A control device for actuating electric circuits in response to a variable condition comprising a sealed housing, a diaphragm dividing said sealed housing into two substantially isolated chambers, means actuated by said condition to move said diaphragm in accordance therewith, a restricted communicating passageway between said chambers, an electrically nonconducting fluid medium substantially filling said chambers and said communicating passageway, and contact means within said passageway having at least one movable element actuated by the differential fluid pressure created in said passageway between said chambers by the motion of said diaphragm resulting from said variable condition.

16. A control device for actuating electric circuits in rsponse to a variable condition comprising a sealed housing, a diaphragm dividing said sealed housing into two substantially isolated chambers, means actuated by said condition to move said diaphragm in accordance therewith, a restricted communicating passageway between said chambers, an electrically nonconducting fluid medium substantially filling said chambers and said passageway, an insert of conducting material movably positioned in said passageway, and contact means mounted in spaced relationship in said passageway whereby said contact means completes such an electric circuit through said conducting insert when the position of said diaphragm is altered in response to said variable condition causing a displacement of said fluid medium along said passageway.

17. A control device for actuating electric circuits in response to a variable condition comprising a sealed housing, a diaphragm dividing said sealed housing into two

substantially isolated chambers, means actuated by said variable condition to move said diaphragm in accordance therewith, a restricted communicating passageway between said chambers, a fluid medium having immiscible conducting and non-conducting portions substantially filling said chambers and said passageway, and contact means mounted in spaced relationship in said passageway whereby said contact means completes such electric circuits through the conducting portions of said fluid medium when the position of said diaphragm is altered in response to said variable condition causing a displacement of said fluid medium along said passageway.

18. A control device for actuating electric circuits in response to a variable condition comprising a restricted passageway, a fluid medium having immiscible conducting and nonconducting portions, said nonconducting portions substantially filling said passageway and said conducting portions being centrally located along said passageway and electrically isolated from the ends of said passageway, means actuated by said variable conditions to move said fluid a limited predetermined distance in said passageway, and contact means mounted in spaced relationship in said passageway intermediate the ends thereof whereby said contact means completes such electric circuits through the conducting portions of said fluid medium when said fluid is in predetermined positions within said distance, the dimension of said restricted passageway being small whereby the relative positions of said conducting and nonconducting portions are maintained irrespective of the position of said passageway and the effects of gravity thereon.

19. A control device fo ractuating electric circuits in response to a variable condition comprising a restricted passageway, a fluid medium having immiscible conducting and nonconducting portions, said non-conducting portions substantially filling said passageway and said conducting portions being centrally located along said passageway and electrically isolated from the ends of said passageway, said fluid medium being movable in said passageway in accordance with said variable condition, and contact means mounted in spaced relationship in said passageway intermediate the ends thereof whereby said contact means completes such electric circuits through the conducting portions of said fluid medium when said conducting portions are adjacent to said contacts, the dimension of said restricted passageway being small whereby the relative positions of said conducting and nonconducting portions are maintained irrespective of the position of said passageway and the effects of gravity thereon.

20. A control device for actuating electric circuits in response to a variable condition comprising a sealed housing defining a first chamber, a second chamber and an interconnecting restricted passageway, a diaphragm comprising one wall of said first chamber, means actuated by said condition to move said diaphragm in accordance therewith, a fluid medium having immiscible conducting

and non-conducting portions substantially filling said chambers and said passageway, and contact means mounted in spaced relationship in said passageway whereby said contact means completes such electric circuits through the conducting portions of said fluid medium when the position of said diaphragm is altered in response to said variable condition causing a displacement of said fluid medium along said passageway.

21. A control device for actuating an electric circuit in response to a variable condition comprising an enclosure, a nonconducting fluid medium substantially filling said enclosure, means for creating a differential pressure in the fluid in isolated parts of said enclosure in response to said variable condition, a passage associated with said isolated parts and through which a portion of the fluid moves, a freely movable conducting element disposed in said portion of fluid filling said passage, and contact means mounted in said passage whereby said contact means completes the electric circuit through said movable element in said fluid medium under predetermined conditions of differential pressure within said enclosure.

22. A control device for actuating electric circuits in response to a variable condition comprising a sealed housing defining a first chamber, a second chamber and an interconnecting restricted passageway, a diaphragm comprising one wall of said first chamber, means actuated by said condition to move said diaphragm in accordance therewith, a fluid medium having immiscible conducting and nonconducting portions substantially filling said chambers and said passageway, and contact means mounted in spaced relationship in said passageway whereby said contact means completes said electric circuit through the conducting portions of said fluid medium when the position of said diaphragm is altered in response to said variable condition causing a displacement of said fluid medium along said passageway, the dimension of said restricted passageway being so small that the relative positions of said conducting and nonconducting portions of said fluid medium are unaffected by gravitational forces.

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