

Feb. 13, 1968

D. J. HAMRICK

3,369,205

MAGNETIC ACTUATOR FOR SWITCHES, VALVES AND THE LIKE

Filed April 13, 1966

3 Sheets-Sheet 1

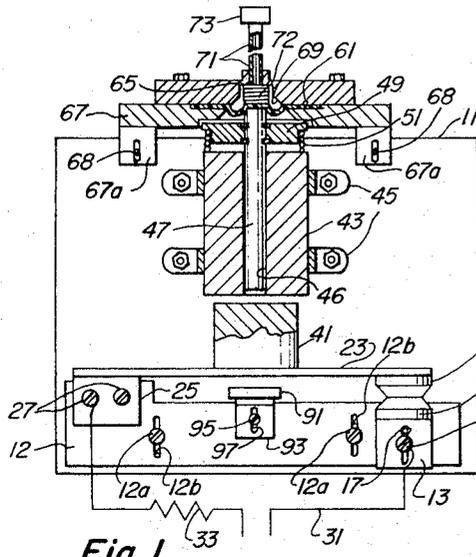


Fig. 1

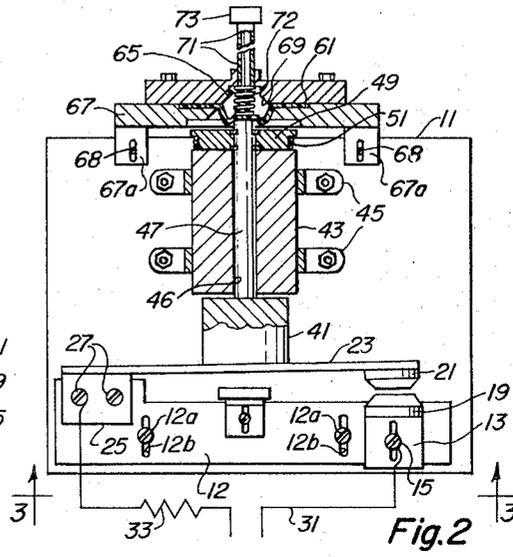


Fig. 2

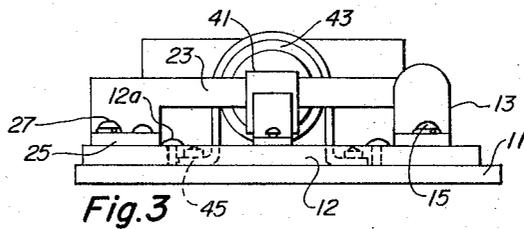


Fig. 3

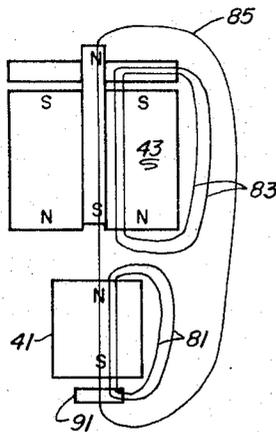


Fig. 4

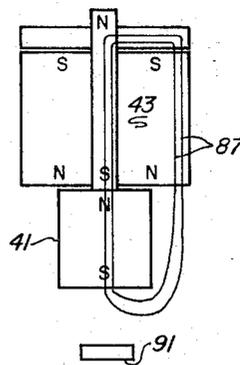


Fig. 5

DONALD J. HAMRICK  
INVENTOR.

BY  
BUCKHORN, BLORE, KLARQUIST & SPARKMAN  
ATTORNEYS

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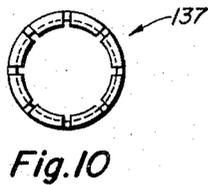
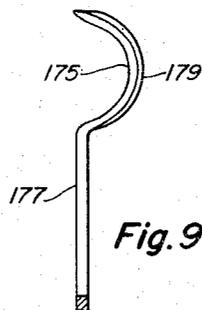
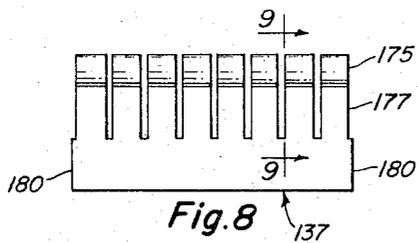
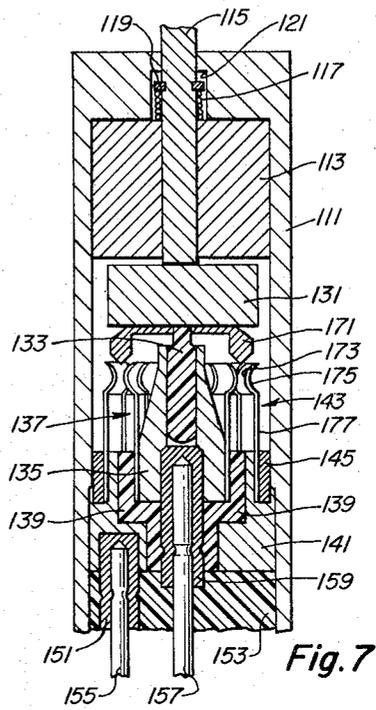
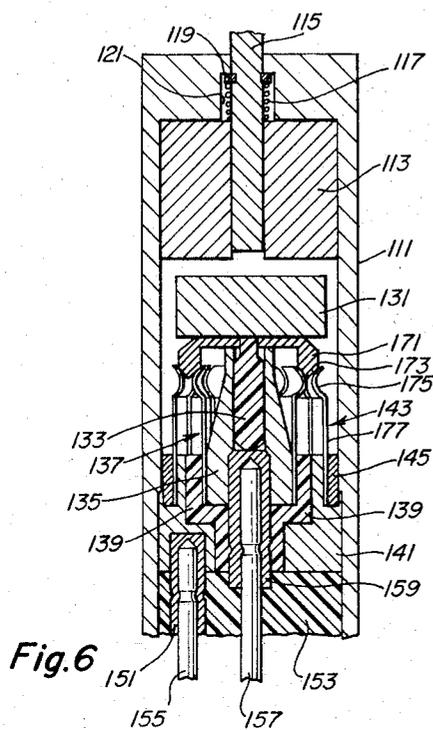
D. J. HAMRICK

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3 Sheets-Sheet 2



DONALD J. HAMRICK  
INVENTOR

BY  
BUCKHORN, BLORE, KLARQUIST & SPARKMAN  
ATTORNEYS

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D. J. HAMRICK

3,369,205

MAGNETIC ACTUATOR FOR SWITCHES, VALVES AND THE LIKE

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3 Sheets-Sheet 3

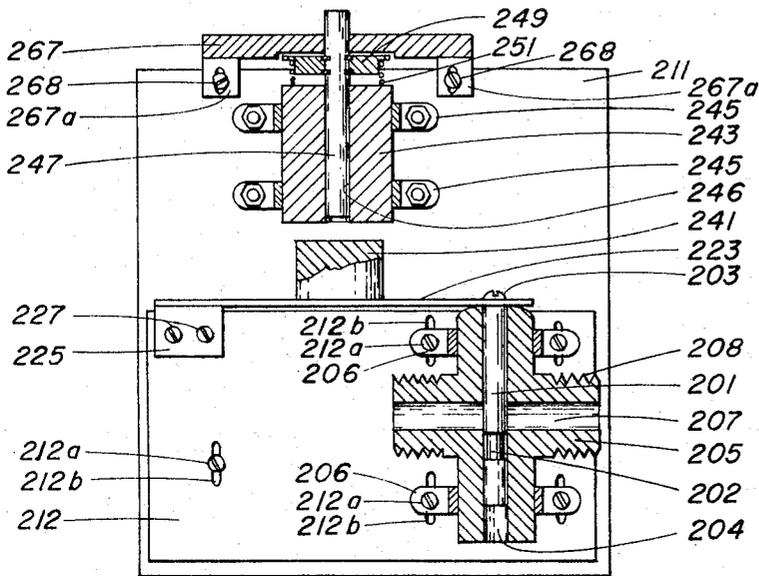


Fig. 11

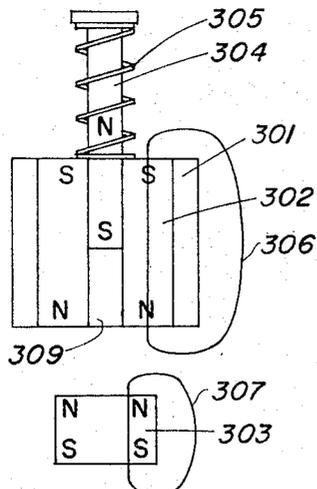


Fig. 12

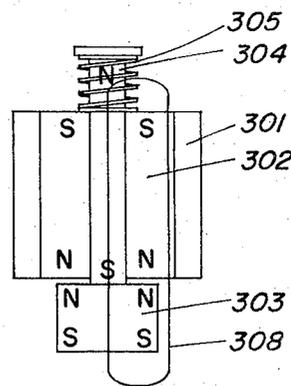


Fig. 13

DONALD J. HAMRICK  
INVENTOR

BY  
BUCKHORN, BLORE, KLARQUIST & SPARKMAN  
ATTORNEYS

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**MAGNETIC ACTUATOR FOR SWITCHES,  
VALVES AND THE LIKE**

Donald J. Hamrick, Vancouver, Wash.

(884 Flaxberry, San Rafael, Calif. 94903)

Continuation-in-part of application Ser. No. 367,100

May 13, 1964. This application Apr. 13, 1966, Ser.

No. 549,097

14 Claims. (Cl. 335-177)

This application is a continuation-in-part of my co-pending application, Serial No. 367,100, filed May 13, 1964 and now abandoned.

This invention relates to a means for producing bistable forces and rapid mechanical motion between two stable positions, and particularly to such a means which makes use of operative elements which produce magnetic force. This actuator may find use in the construction of electrical switches, valve mechanisms, and similar devices.

Magnetic actuators have previously been used in the construction of electric switches, but forces needed to effect their operation have either been large, or else such forces have been required to be effective over a substantial range of movement.

An object of the present invention has been to provide a magnetic actuator which overcomes the above disadvantages and specifically which can be operated by a very small force which is required to act through a very small range of movement.

I have discovered an arrangement of magnetic fields of two magnetic members repulsively oriented and a movable ferromagnetic member whereby when the ferromagnetic member is arranged in a magnetically attracted predetermined position relative to one of the members' magnetic fields, a minute movement of the ferromagnetic member in a predetermined direction yielding to attractive forces will cause the other magnetic member to snap suddenly toward the ferromagnetic member. Such sudden motion may be used if desired to effect a separation of, or an engagement between, a pair of switch contacts. I believe this sudden action is caused by a magnetic field shift or reorientation of the flux lines of the magnetic fields of the magnets.

A more specific object of the invention is to provide a magnetic actuator in which there is a fixed master magnet and a movable slave magnet arranged in repulsive adjacent relation to one another. A ferromagnetic plunger or core projects into a passageway in the master magnet in such a way that it is restrained by a spring from assuming the magnetic equilibrium position with reference to the master and slave magnets, which equilibrium position may be attained by movement of the ferromagnetic plunger. The arrangement is such that if the plunger is moved a minute distance further toward the slave magnet a field shift or reorientation is effected to short the repulsive fields and to create attractive fields so that the slave magnet snaps toward the master magnet. The force required to move the plunger this minute distance is very small because the plunger actuating force need only be greater than the differential force between that exerted by the spring and the magnetic force tending to move the plunger further into the passage in the master magnet.

It is a further object of this invention to provide a magnetic actuator which may be effectively used as a means for effecting the separation or the engagement of a pair of electrical switch contacts.

It is an additional object of this invention to provide a magnetic actuator which may be effectively used as a means for effecting the opening, closing or other actuation of a valve for fluids.

It is an additional object of the invention to provide a magnetic actuator which may be effectively used as a

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means for effecting mechanical motion for effecting such purposes as the engaging of a clutch.

It is a still further object of the invention to provide a magnetic actuator of novel construction.

5 Various other objects of the invention will be apparent from the following description taken in connection with the accompanying drawings wherein:

10 FIG. 1 is a plan view of an embodiment of the present invention, showing it incorporated in an electrical switch, which is connected in a simple circuit with the switch closed;

FIG. 2 is a view similar to FIG. 1, but showing the actuator in the position which leaves the switch open;

15 FIG. 3 is an elevational view taken in the direction of the arrow 3-3 in FIG. 2;

FIG. 4 is a diagrammatic view of certain essential elements of my actuator, with the plunger shown in its first position;

20 FIG. 5 is a diagrammatic view similar to FIG. 4 but showing the plunger as having been moved to its second position, to effect a reorientation of the magnetic lines of force;

FIG. 6 is a view of a modified form of the actuator used as a switch which is very much like that in FIG. 1, but showing a more sophisticated contact construction, the switch being closed;

FIG. 7 is a view similar to FIG. 6 showing the switch in its open position;

30 FIG. 8 is an unrolled elevational view of the inner contact member of FIG. 6;

FIG. 9 is an enlarged sectional view of the contact member taken along line 9-9 of FIG. 8;

FIG. 10 is an end or plan view of the inner contact member in its rolled or installed condition;

35 FIG. 11 is a plan view similar to FIG. 1, showing an embodiment of my invention arranged as an actuator for a fluid control valve;

40 FIG. 12 is a diagrammatic view of another embodiment of my invention, in which the master magnet is shown as an electromagnet rather than as a permanent magnet, the operating principle of the device remaining unchanged, but allowing a change in current in the electromagnet, and the plunger shown in its first position; and

45 FIG. 13 is a diagrammatic view similar to FIG. 12, but showing the plunger as having been moved to its second position.

Referring to FIGS. 1-3, the particular embodiment of the invention shown, which is merely illustrative of one of the many ways in which my invention may be used in the construction of a switch, comprises a supporting plate 11 of nonmagnetic material on which a mounting plate 12 of nonmagnetic and electrically insulative material is secured by a pair of screws 12a fitting in a pair of slots 12b. A contact bracket 13 is mounted on the plate 12 by means of a screw 15 which passes through an elongated slot 17 in the bracket to facilitate adjustment of the position of the bracket relative to the plate 12 for a reason to presently appear. The bracket carries a first contact 19 shown in engagement with a second contact 21. The latter is carried by one end of a spring leaf 23. The other end of the leaf has a flange portion 25 which is secured by a pair of screws 27 to the plate 12. A simple circuit 31 having a resistance load 33 is shown connected to the screws 15 and 27.

65 A solid cylindrical permanent magnet 41 is secured to the leaf 23 intermediate the length of the latter and is arranged in repulsive coaxial relation to a larger annular or hollow cylindrical magnet 43. The latter is fixedly mounted on the plate 11 by straps 45 and has a bore 46 70 which slidably receives a soft iron plunger 47. The plunger has a flange 49 adjacent its outer end, and arranged between this flange and the magnet is a com-

pression spring 51. The parts are so dimensioned and arranged that the spring restrains the plunger against assuming a magnetic equilibrium position with respect to the magnet 43 and in fact disposes the plunger in a predetermined threshold or critical position. In such threshold or critical position, a minute movement of the plunger farther into the master magnet 43 will cause the slave magnet to snap toward the master magnet, despite the fact that the two magnets are arranged in repulsive relation. The reason for such action will be shortly explained.

As an example of one of many ways in which plunger motion may be effected, I have shown a rolling diaphragm 61 secured to the outer end of the plunger 47. The flange portions of the diaphragm are clamped between a pair of body members 65 and 67, the latter being mounted on the plate 11 by screws 68 fitting through elongate slots in ears 67a on body member 67. Member 65 is formed to provide a cavity or chamber 69 for the diaphragm, which chamber is filled with fluid and is connected to a fluid filled capillary tube 71. The chamber 69 also contains a compression spring 72 arranged between the diaphragm and a shoulder on the body member 65.

The box 73 is to indicate any means for causing an increase or decrease in the pressure of the fluid in the chamber and tube. An increase in pressure will effect movement of the plunger from its FIG. 1 to its FIG. 2 position, while a subsequent decrease in pressure will allow the spring 51 to retract the plunger and cause it to reassume its FIG. 1 position. The extent of movement of the plunger has been exaggerated in FIGS. 1 and 2 for purposes of illustration. The actual movement may be only .006-.007 inch, or even as little as .003 inch.

FIGS. 4 and 5 are provided to show the theory of operation of this switch that seems best to conform to the physical events which occur. FIG. 4 shows that the magnetic lines of force 81 of the magnet 41 are in repulsive relation to the magnetic lines of force 83 of the magnet 43. It is believed that there are a few magnetic lines of force 85 passing through the plunger 47 and outwardly and around both magnets. The spacing between the magnets in FIG. 4 has been exaggerated for purposes of illustration.

When the plunger 47 is moved from its FIG. 4 position to its FIG. 5 position (a much lesser distance than that shown in the drawings) apparently a field shift or field reorientation occurs as shown in FIG. 5, to short the repulsive fields and to create attractive fields because the magnet 41 snaps toward the magnet 43 (and engages the plunger 47) to separate the contacts 19 and 21. It is believed that most of the magnetic lines of force 81 and 83 combine as lines 87 to assume the relationship shown in FIG. 5, completing a circuit in part passing through the magnet 43.

When the pressure of the fluid on the diaphragm 61 decreases, the spring 51 causes the plunger to be retracted slightly, at which time the magnetic field apparently again shifts or reorients itself to resume the FIG. 4 positions. When this occurs, the magnet 41 snaps away from the magnet 43 to close the contacts 19 and 21.

One advantage of the FIGS. 1-3 construction is that the strong repulsive forces between the magnets 41 and 43 causes firm engagement between the contacts 19 and 21, when the contacts are in engagement, and hence prevents arcing across the contacts which might otherwise occur.

In order to maintain such firm contact pressure until the abrupt separation of the contacts, an iron piece 91 may be provided behind the slave magnet 41 and supported by a bracket 93 on the plate 12. The bracket 93 is secured in place by a screw 95 which passes through an elongated slot 97 in the bracket. This iron piece has a force of attraction between it and the slave magnet so that the slave magnet will be prevented from gradual movement toward the advancing plunger. If the latter occurred, the contact pressure between the contacts 19

and 21 would decrease, and thus create an increased resistance across the contacts and arcing across such contacts might occur, depending, of course, on the magnitude of the voltage and current being controlled.

The slots in the parts 12, 15, 67 and 93 enable initial adjustment of the parts so that the leaf 23 and its contact 21 and slave magnet 41 are properly disposed relative to the fixed contact 19 and the permanent magnet 43, respectively. A suggested setting up procedure comprises adjusting the bracket 13 to attain the desired pressure of contact between the contacts 19 and 21. Thereafter, the pressure of the fluid in the chamber 69 and tube 71 is brought up to its actuating value so as to advance the plunger 47 toward the slave magnet 41. The screws 12a are loosened and the plate 12 is shifted toward the master magnet 43 until the slave magnet snaps toward the plunger 47. The screws 12a are now tightened up to secure the plate 12 fixedly to the plate 11. Afterwards, the fluid pressure on the diaphragm 61 is decreased to allow the contacts to engage. Next, during successive build-ups of fluid pressure, the bracket 93 and its piece 91 are shifted back and forth to obtain the best abrupt separation of the contacts 19 and 21.

It will be appreciated that FIGS. 1-3 show only a rather simple form of my device used as a switch, and the device can assume numerous forms without departing from the important concepts of the present invention.

Optimum results with my actuator, i.e., minimum operating force and minimum plunger movement, can be obtained by following certain guidelines which are set forth below. (1) The slave magnet should be solid. (2) The slave magnet should be of smaller diameter than the master magnet. (3) The diameter of the slave magnet must be larger than the bore diameter of the master magnet. (4) The diameter of the slave magnet should be greater than the combined dimensions comprising the bore diameter of the master magnet plus the wall thickness of the master magnet. (5) The bore diameter of the master magnet should be less than the wall thickness of the master magnet. (6) The plunger 47 should be longer than the master magnet. (7) The plunger preferably is of soft iron having high permeability so that it will quickly assume magnetic qualities and quickly lose them. In connection with guideline (5) above, the size of the primary parts is preferably such that the cross-sectional area of the plunger is substantially equal to the difference in area of two circles having diameters respectively that of the master and slave magnets.

I find that barium ferrite permanent magnets, particularly oriented barium ferrite permanent magnets, are advantageously employed in my switch because they not only have strong magnetic qualities but are electrically nonconductive, so that the use of separate insulators in certain places can be dispensed with.

It is pointed out that the magnets are located along an axis which is located intermediate the length of the leaf 23 in order to achieve better snap action between the contacts 19 and 21. However, the invention is not intended to be limited to such an arrangement, or indeed to the particular arrangement in FIGS. 1-3, which is only exemplary of one embodiment of my invention.

The flange or collar 49 serves an additional function to that of an abutting surface for the spring 51, and that is to reduce the reluctance of the path along which the lines of magnetic force travel. This is apparent from FIGS. 4 and 5.

While in FIGS. 1-3 the slave magnet 41 is shown mounted on spring leaf 23 which flexes, I also contemplate a construction where the lefthand end of the leaf, as the parts are shown in FIGS. 1 and 2, could be pivotally mounted. Under such circumstances, the proper contact pressure between contacts 19 and 21 would be obtained by virtue of the repulsive forces between magnets 41 and 43. It still might be desirable to adjustably mount the bracket 13 in order to locate the leaf in a position so

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that it extends normal to the axis of the plunger 47 rather than being askew with respect to such axis.

FIGS. 6-10 show the switch with a more sophisticated contact structure for the purpose of controlling the flow of substantial current. The switch includes a tubular housing 111 of nonmagnetic material in which an annular permanent magnet 113 is fixed. The magnet slidably receives a cylindrical soft iron plunger 115 which is urged by a compression spring 117 to assume the FIG. 6 position. The spring 117 is arranged between the magnet 113 and a snap ring 119 on the plunger 115. The snap ring 119 is urged by the spring 117 to bear against a shoulder provided by a counterbore 121 in the housing 111.

Disposed in repulsive relationship next to the master magnet 113 is a solid cylindrical slave magnet 131 having a loose or clear fit within the housing 111. Adhesively secured in coaxial relation to the slave magnet is a nonmagnetic guide pin 133 which is shown as being of plastic material. The pin is slidably received by a tubular inner terminal member 135 of electrically conductive material, such as brass or even iron if it is to have an effect on the slave magnet 131 similar to the effect that piece 91 has on slave magnet 41. The guide pin 133 guides the slave magnet 131 for movement relative to the housing or case 111.

The inner terminal member 135 is surrounded by an inner contact member 137 of ring form. The inner terminal member and the inner contact member are supported by a cup-like insulator member 139 which is in turn supported by a brass outer terminal member 141 of annular form. The latter is fixedly held (such as by threads) within the housing or case 111 and carries an outer ring type conductor member 143. A ring type retainer 145 holds the conductor member 143 in place on the outer terminal member 141.

A brass outer ferrule 151 fits upwardly through a body of sealing material 153 and fits into a blind hole in the outer terminal member 141. The ferrule 151 receives a conductor 155 which leads to an external circuit, not shown, a second conductor 157 for the circuit is secured within an inner ferrule 159 which in turn is secured within a sleeve portion of the insulator 139 and projects upwardly into the inner terminal member 135. The upper end of the ferrule 159 also serves as to stop for the guide pin 133 to determine the maximum separation of the slave magnet 131 and the master magnet 113. The plug 153 is formed by pouring sealing material into the case 111 after the ferrules are inserted in place.

The slave magnet carries a brass contact ring 171 having an apical contact portion 173 for nesting engagement between reversely facing curved tips 175 of the flexible fingers 177 of the contact members 137 and 143. The contact members may be phosphor bronze and portions of the tips which engage the contact ring 171 may be coated with silver 179 (FIG. 9) for better electrical conduction.

FIG. 8 shows the inner contact member 137 in its flat unrolled condition. Preferably the contact members are formed to have a rolled condition so that they may be simply inserted in place.

The many flexible fingers of the contact members provide substantial areas of contact with only relative light contact pressure to facilitate the ready passage of substantial current at substantial voltage without arcing. For instance, a switch like that in FIGS. 6-10 can handle around 4000 watts, i.e., 245 volts with 16.3 amperes.

The operation of the FIGS. 6-7 form of the invention is believed obvious from the description of the FIGS. 1-3 construction. When the plunger 115 is advanced a slight distance farther into the master magnet 113, the slave magnet 131 suddenly snaps toward the master magnet to separate the contact ring 171 from the contact members 137 and 143.

Referring to FIG. 11, the valve mechanism shown, which is illustrative of one of the many ways in which

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my magnetic actuator may be used to control a valve, comprises a supporting plate 211 of nonmagnetic material on which a mounting plate 212 of nonmagnetic material is secured by screws 212a fitting in slots 212b. One end of a spring leaf 223 has a flange portion 225 which is secured by a pair of screws 227 to the plate 212. To the other end of the spring leaf a spool valve core 201 containing a groove 202 is secured by the screw 203. This valve core is a sliding fit in the channel 204 in the valve body 205 which is secured to the supporting plate 212 by straps 206. The valve body contains a fluid channel 207 intersecting channel 204. The valve core blocks channel 207 when it is in its position of maximum insertion into the valve body, but when the valve core is not in this position, the groove 202 permits fluid passage through channel 207. Threaded connections 208 are provided for connecting the valve to a suitable fluid circuit.

A solid cylindrical permanent magnet 241 is secured to the leaf 223 intermediate the length of the latter and is arranged in repulsive coaxial relation to a larger annular or hollow cylindrical magnet 243. The latter is fixedly mounted on the plate 211 by straps 245 and has a bore 246 which slidably receives a soft iron plunger 247. The plunger has a flange 249 adjacent its outer end, and arranged between this flange and the magnet is a compression spring 251. The plunger and flange are prevented from moving outward by member 267 which is mounted on the plate 211 by screws 268 fitting through elongated slots in ears 267a on member 267. The parts are so dimensioned and arranged that the spring restrains the plunger against assuming a magnetic equilibrium position with respect to the magnet 243 and in fact disposes the plunger in a predetermined threshold or critical position. A minute movement of the plunger farther into the master magnet 243 will cause the slave magnet to snap toward the master magnet.

It is believed that the operation of the valve shown in FIG. 11 will be clear from the discussion of the switch shown in FIGS. 1-3.

Referring to FIG. 12, showing diagrammatically an embodiment of my invention in which the master magnet is an electromagnet, this embodiment comprises a solenoid 301 having an iron core 302, ferromagnetic plunger 304 arranged to be slidable in channel 309 in the core but restrained by spring 305 from assuming a position of magnetic equilibrium, and cylindrical permanent slave magnet 303 which is either magnetically attracted toward, or repelled from, the master magnet, depending on the position of the ferromagnetic plunger. Current flows in the solenoid in a sense such as to create a magnetic field equivalent to that of a permanent magnet tending to repel the slave magnet.

Typical lines of force 306 and 307 are shown for the case, in FIG. 12, in which the slave magnet is repelled from the master magnet, and in FIG. 13 a typical line of force 308 is shown for the case in which the ferromagnetic plunger has been moved so as to cause an attraction of the slave magnet. The operation of this embodiment of the invention is as previously described in connection with FIGS. 4 and 5.

It is evident that my invention may be used in many other ways than those described above. My device, being a means for producing sudden motion of a magnet from one determined position to another, may be used, for example, in the construction of a small clutch which is engaged or disengaged accordingly as the slave magnet is in a position near to or far from the master magnet. It may also be used in an optical shutter or in a visual indicator, by linking a lightweight vane to the slave magnet to block a light path or provide a visible indication when the slave magnet is in its position near to or, if desired, far from the master magnet. It may also be used in the construction of a means for producing signal pulses as a consequence of small mechanical movement, since a small electromagnetic coil placed in the magnetic field

of the slave magnet will have a voltage pulse generated in it as the magnetic flux through it changes when the slave magnet moves suddenly.

Since the ferromagnetic plunger may be caused to move not only by the application to it of mechanical forces, but also by the application to it of magnetic forces by an electromagnetic coil, which plunger motion causes the slave magnet to move from one of its terminal positions to the other, it is evident that my actuator may be used in the construction of sensitive electromagnetic relays and other electromagnetically operated devices.

Although the embodiments of my invention which have been described have involved the use of a hollow cylindrical master magnet, it is evident that this master magnet can be replaced by a plurality of magnets without departing from the spirit of this invention, provided only that this plurality of magnets effectively surrounds a passage for the motion of the ferromagnetic plunger.

Having described the invention in what is considered to be preferred embodiments thereof, it is desired that it be understood that the invention is not to be limited other than by the provisions of the following claims.

I claim:

1. In a magnetic device for producing motion, a master magnet structure having a passage through, a slave magnet arranged in adjacent relation to one end of said passage, and repelled by the master magnet structure, said master magnet structure and slave magnet being mounted for motion relative to one another, and ferromagnetic means mounted for motion through said passage in said master magnet structure to cause the slave magnet to be magnetically attracted in the direction of the master magnet structure.
2. A device according to claim 1, wherein said slave magnet is mounted for motion toward and away from said master magnet structure.
3. A device according to claim 2, wherein said passage through said master magnet structure is a hollow bore, and wherein said slave magnet is arranged in coaxial relation to said bore, and wherein said ferromagnetic means is a plunger movable in said bore.
4. A device according to claim 3, wherein there are spring means constraining said plunger to assume a mag-

netically nonequilibrium position relative to said master magnet structure.

5. A device according to claim 3, wherein there are spring means constraining said plunger to assume a magnetically nonequilibrium position relative to said master magnet structure, such that said plunger is magnetically urged toward the slave magnet by the master magnet structure.

6. A device according to claim 5, wherein there are contact means actuated by the movement of said slave magnet.

7. A device according to claim 2, wherein the master magnet structure and the slave magnet are permanent magnets.

8. A device according to claim 3, wherein the master magnet structure and the slave magnet are permanent magnets.

9. A device according to claim 4, wherein the master magnet structure and the slave magnet are permanent magnets.

10. A device according to claim 5, wherein the master magnet structure and the slave magnet are permanent magnets.

11. A device according to claim 6, wherein the master magnet structure and the slave magnet are permanent magnets.

12. A device according to claim 5, wherein there are fluid channel closing means actuated by the movement of said slave magnet.

13. A device according to claim 12, wherein the master magnet structure and the slave magnet are permanent magnets.

14. A device according to claim 6, wherein the master magnet structure is a master permanent magnet means, and wherein the slave magnet is a slave permanent magnet means.

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