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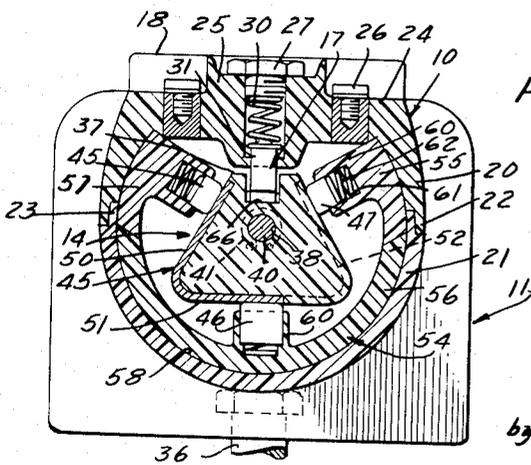
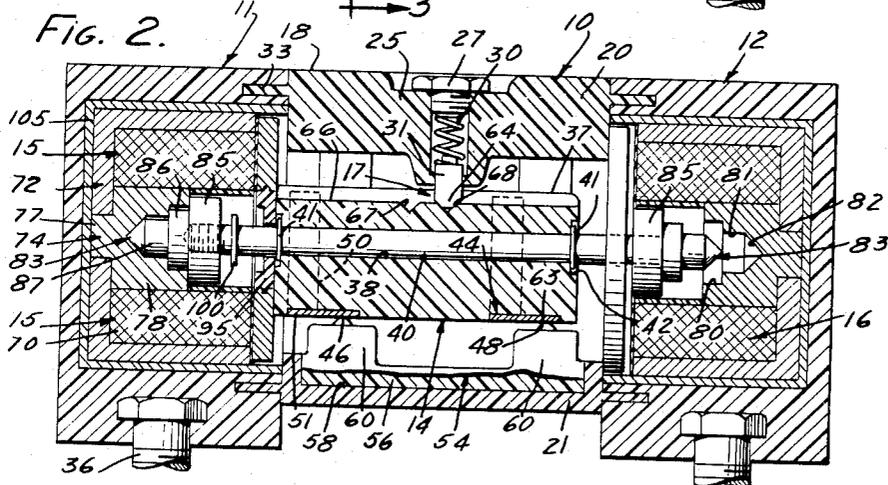
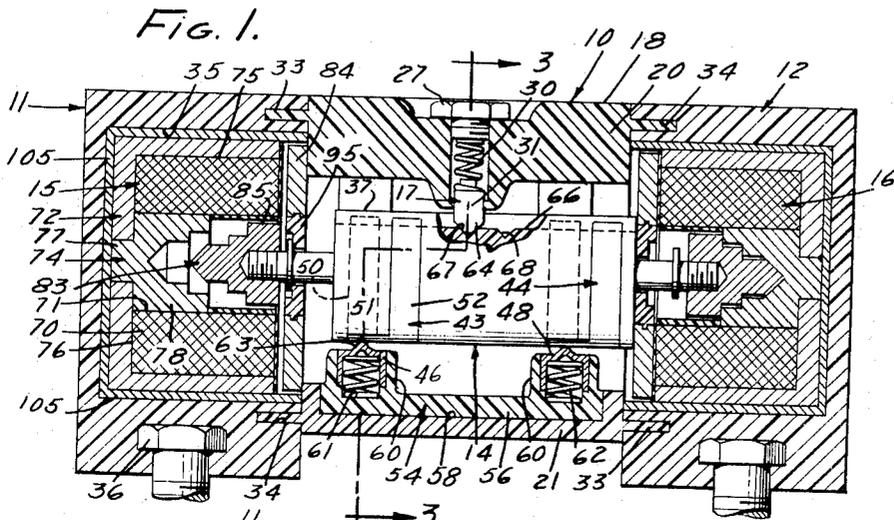
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3,223,802

SOLENOID HAVING A TWO-PIECE ARMATURE

Filed June 14, 1963

2 Sheets-Sheet 1



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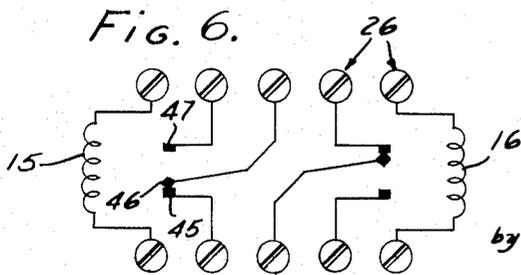
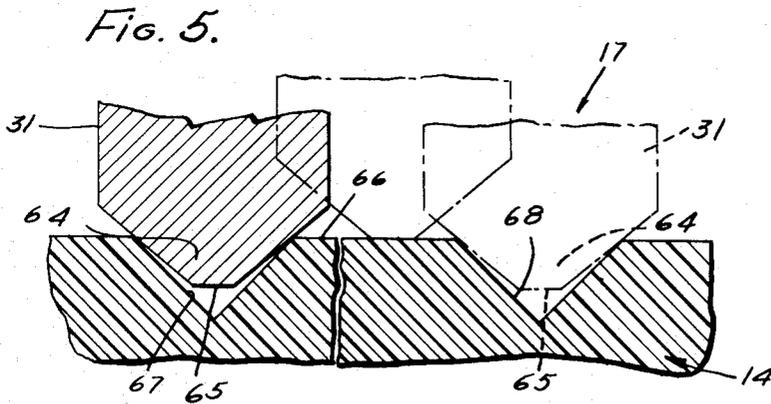
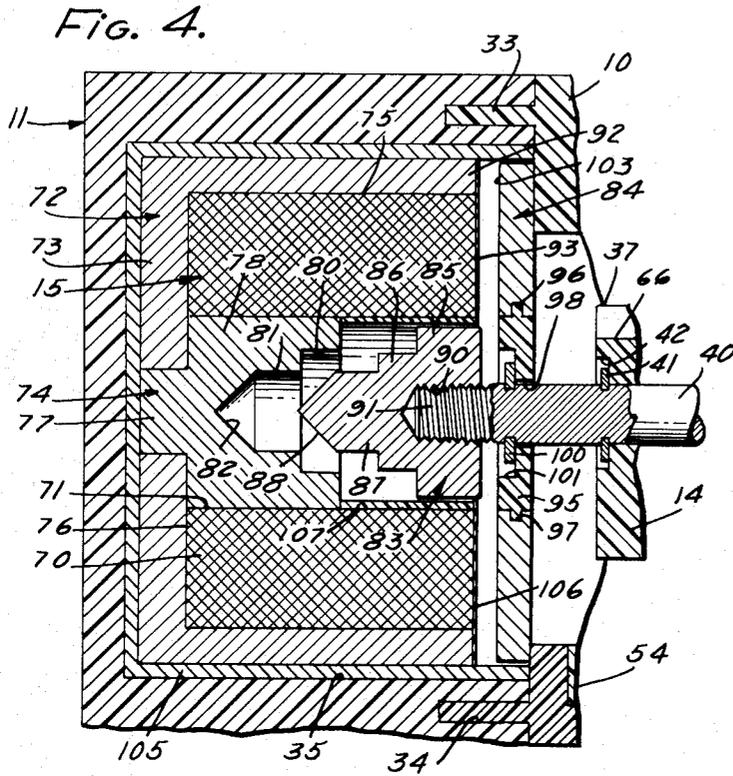
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SOLENOID HAVING A TWO-PIECE ARMATURE
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tion of California

Filed June 14, 1963, Ser. No. 287,896

10 Claims. (Cl. 260-98)

This invention relates generally to electromechanical devices and particularly relates to a solenoid which is capable of exerting a relatively large force during the initial movement of the armature and thereafter a relatively small force during the remainder of the armature travel.

For some applications solenoids are required which must overcome a large initial resistance to the movement of the armature. After this initial resistance to the armature movement is overcome, only a relatively small force is required for the remainder of the travel of the armature. For example, the solenoid may be required to open or close a valve. When a large fluid pressure acts on the valve, there may be a very large initial resistance in opening the valve. Once the valve has been opened to a certain extent only a small force is necessary to move the valve to the fully open position.

The same is true for certain latching relays of the type where two solenoids pull the relay from one fixed position to another. The latching or detent mechanism may be purposely made in such a manner that the relay is locked by a large force so that the relay is able to withstand large acceleration forces.

The solenoid of the present invention will be explained in connection with a latching relay to illustrate the problem which the solenoid of the invention is designed to solve. However, it will be understood that the solenoid of the invention may be used for other purposes, for example, for opening or closing fluid valves.

In a conventional solenoid where the armature moves through a relatively large distance, the initial magnetic force attracting the armature is generally low. This is due to the fact that the armature is spaced from the attracting solenoid a relatively large distance and therefore the magnetic force is initially low. On the other hand, at the end of the travel of the armature, the attracting force increases substantially because the armature is closer to the solenoid.

Thus, a conventional solenoid provides the smallest attracting force during its initial travel where the largest force may be required for some applications. In order to obtain a sufficiently large attracting force with a conventional solenoid during the initial travel of the armature it may be necessary to increase the electric power supplied to the solenoid winding and to increase the size and weight of the entire solenoid. This may not be possible for certain applications, particularly for air-borne latching relays.

It is accordingly an object of the present invention to provide a solenoid of relatively light weight and which is capable of exerting a relatively large force during the initial movement of its armature and thereafter a relatively small force during the remainder of the travel of the armature.

Another object of the present invention is to provide a solenoid of the type referred to which requires little electric power for its operation.

A further object of the present invention is to provide a solenoid of the character referred to cooperating with a detent mechanism for a relay which locks the relay against very substantial acceleration forces for use with satellites and the like which are subjected to large acceleration forces upon launching and change of attitude.

A solenoid, in accordance with the present invention,

provides, when energized, a relatively large force during the initial portion of movement of its armature and a relatively small force during the remaining portion of movement of its armature to overcome an initial large resistance to the armature movement.

The solenoid of the invention includes a solenoid winding which is adapted to be energized and which is of cylindrical shape to provide a hollow interior space. A core shell of magnetizable material may be provided and may surround the cylindrical surface of the winding, one flat surface of the winding, and may extend partially into the interior space of the solenoid winding.

There is further provided a movable armature for the solenoid which is adapted to be attracted by the winding and the armature shell when the winding is energized. This armature includes two elements. The first is a disc-shaped flapper disposed adjacent the free flat surface of the winding and which provides the initial large force of the solenoid. The flapper is spaced a relatively small distance from the solenoid's attracting surface so that it develops initially a large force.

The second element of the armature consists of a plunger which is mechanically coupled to the flapper. The plunger is disposed in the interior space of the solenoid and is adapted to be attracted by the solenoid winding. This plunger is spaced from the center of the core a relatively large distance and provides the relatively small force which moves the armature for the remainder of its travel.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIG. 1 is a longitudinal sectional view, partly in elevation of a latching relay including two solenoids in accordance with the present invention, the relay being shown in one of its locked positions;

FIG. 2 is a longitudinal sectional view, parts being shown in elevation, similar to that of FIG. 1 but illustrating the relay in the other one of its locked positions;

FIG. 3 is a cross-sectional view taken on line 3-3 of FIG. 1 and illustrating particularly the relay armature with its brushes and contacts;

FIG. 4 is a longitudinal sectional view on an enlarged scale of one of the solenoids of the relay of FIG. 1;

FIG. 5 is a sectional view on an enlarged scale illustrating the detent mechanism of the latching relay of FIG. 1; and

FIG. 6 is a schematic representation and circuit diagram of the relay with its solenoid windings.

Referring now to the drawings, and particularly FIGS. 1 to 3, there is illustrated a double solenoid or latching relay embodying two solenoids in accordance with the present invention.

The latching relay generally includes a main housing 10, two end caps 11 and 12, a switch armature 14 which is reciprocated by two solenoids 15 and 16 which are of identical construction. The switch armature 14 is also provided with a detent mechanism 17 which is illustrated in greater detail in FIG. 5.

The main housing 10 is of generally cylindrical shape, as shown in FIG. 3, and is provided with a generally flat top portion 18. The main housing 10 preferably is made of two portions 20 and 21 for ease of assembly. The upper housing portion 20 may be provided with an outer projection 22 while the lower housing portion 21 has a corresponding inner projection 23. This permits the two housing portions to be readily sealed together, as will be

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more fully explained hereinafter. The top 18 of the main housing may be provided with two elongated depressions 24 disposed on either side of a central projection 25. A plurality of screws 26 may extend through the depressed main housing portions 24 for connecting thereto electric leads. A screw 27 extends through the central projection 25 of the main housing and serves as a bearing for a spring 30 which urges a conical detent 31 downwardly.

The main housing 10 is provided with two laterally extending cup-like projections 33 engageable with corresponding cylindrical recesses 34 in the two end caps 11 and 12. In this manner the main housing 10 may be secured to the two end caps 11 and 12.

Since the two end caps 11 and 12 are identical, only one of them will now be described. The end cap 11 as shown in FIG. 3, is of substantially rectangular cross-section and forms an internal cylindrical space 35 in which the solenoid 15 is disposed. The end cap 11 may also be provided with a threaded bolt 36 having its head molded into the end cap 11 with the threaded portion extending outwardly for securing the latching relay to a suitable chassis or support.

Before describing the solenoids 15 and 16 of the invention, the switch armature 14 and associated parts will now be described.

The switch armature 14 consists of a suitable insulating material and generally has the shape of a triangular prism, as shown particularly in FIG. 3, having a flat top portion 37.

The switch armature 14 is provided with a central cylindrical opening 38 extending therethrough. A central shaft 40 extends through the switch armature 14 and is connected to the two armatures of the two solenoids 15 and 16, as will be more fully described hereinafter. The switch armature 14 is secured to the shaft 40 by two snap discs 41 which may snap into suitable recesses in the shaft 40 and which are disposed in flat cylindrical recesses 42 at either end of the switch armature 14. Thus, the switch armature 14 is firmly secured to the central shaft 40. As a result, the switch armature 14 and its central shaft 40 are reciprocated upon energization of the two solenoids 15 and 16 in sequence.

The switch armature 14, as illustrated, is designed to provide two double-pole, double-throw switches. However, it will be understood that instead of two, three or more such switches, or a single switch may be provided. Furthermore, instead of providing a double-pole, double-throw switch, it is also feasible to provide a single-pole double-throw switch.

To this end, the switch armature 14 is provided with two contact strips 43 and 44. Each of the two contact strips 43 and 44 extend over the three triangular-shaped side walls of the switch armature 14, but does not extend over the flat top surface 37. Three contact brushes 45, 46 and 47, cooperate with the contact 43. Similarly, three brushes cooperate with the contact 44 of which brush 48 is shown in FIGS. 1 and 2. The detailed construction of the brushes, such as 45 through 48, will be subsequently explained.

The contact strip 43 consists of three connected portions 50, 51 and 52 cooperating respectively with the three brushes 45, 46, and 47. Preferably, the contact portions 50, 51 and 52 are embedded in the switch armature 14 so that they are flush with the outer surface thereof. In the position of the relay of FIG. 1, brush 45 is in contact with the contact portion 50. Similarly, the brush 46 is in contact with the contact portion 51. However, the brush 47 is out of engagement with the contact portion 52. On the other hand, when the relay is in the position of FIG. 2, brush 45 is out of contact with the contact portion 50 while the brushes 46 and 47 are respectively in contact with the contact portions 51 and 52.

As a result, an electric circuit connected between brushes 45 and 46 will be closed with the relay in the

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position of FIG. 1 and open in the position of FIG. 2. On the other hand, an electric circuit connected between brushes 46 and 47 will be open when the relay is in the position of FIG. 1 but will be closed when the relay is moved into the position of FIG. 2. Accordingly, brushes 45 to 47 contact strip 43 to form a double-pole, double-throw switch.

It will be noted that the contact portion 51 is wide enough so its brush 46 remains in contact therewith regardless of the position of the relay. It will now be apparent that the contact 44 is made in the same manner as the contact 43 and provides two closed contacts in one position of the relay and two other closed contacts in the other position of the relay. Accordingly, further description of the contact 44 is not deemed to be necessary.

The respective six brushes such as 45 through 48 are mounted in a suitable brush holder 54 shown particularly in FIG. 3. The brush holder 54 is preferably made of three separate pieces 55, 56 and 57 mainly for ease of assembly. The outer surface of the brush holder 54 is generally cylindrical and fits into the generally cylindrical internal recess 58 of the main housing 10. As shown particularly in FIG. 3, the brush holder 54 has three projections 60, each forming an elongated pocket 61 for receiving the respective brushes 45 through 47. Each of the brushes is outwardly biased by a bias spring 62 in the recess 61 which is preferably a coil spring. Each of the brushes 45 through 48 may, for example, consist of a piece of sheet metal which has bent into a substantially U-shape with an elongated central projection 63 which contacts the respective contacts 43 or 44.

The switch armature 14 is preferably locked in its two positions by the detent mechanism generally indicated at 17. The detent mechanism includes a movable detent member 31 having a conical tip 64, which may have a flat end 65 shown particularly in FIG. 5. This detent cone 31 is pressed downwardly by the force of the spring 30 bearing against the screw 27. The top portion 37 of the switch armature 14 has a recessed portion 66 which is generally flat and is provided with two conical recesses 67 and 68 with which the detent cone may engage. Thus, in FIG. 1, the detent cone 31 engages the conical recess 67 while in FIG. 2, it engages the recess 68. The detailed operation of the detent mechanism will be explained hereinafter in connection with FIG. 5.

Turning now to the two solenoids 15 and 16, it will be noted that the solenoids are of identical construction and therefore only one of them will be described. In this connection, reference is particularly made to FIG. 4 showing an enlarged view of the solenoid 15. The solenoid 15 includes a solenoid winding 70 which is of cylindrical shape and provided with an internal cylindrical recess 71. The solenoid winding 70 is surrounded by a core shell generally indicated at 72. The core shell 72 may be made of two separate pieces 73 and 74 for ease of manufacture. Thus, the core shell piece 73 is of generally cup shape and surrounds the cylindrical outer surface 75 of the solenoid winding 70 and one of its flat surfaces 76.

The other core shell piece 74 has a central cylindrical portion 77 which together with the core shell portion 72 forms a cup. The core shell portion 74 extends partially into the cylindrical hollow space 71 formed by the solenoid winding 70. This portion 78 is of generally cylindrical shape and is provided with an outer cylindrical recess 80 and intermediate cylindrical recess 81 of smaller diameter and an inner conical recess 82. A plunger 83 forms part of the armature of the solenoid 15. The other portion of the solenoid armature is formed by a flapper 84.

The plunger 83 has a shape complementary to that of the inner or cylindrical core shell 78. Thus, the plunger 83 has an outer cylindrical portion 85 followed by a second or intermediate cylindrical portion 86 of smaller diameter which in turn is followed by a third cylindrical

portion 87 of still smaller diameter. The inner end of the plunger 83 is formed by a conical portion 88. Thus, it will be seen that when the plunger 83 is attracted upon energization of the solenoid 15, it will snugly fill the respective recesses 80, 81 and 82 of the core shell portion 78.

The plunger 83 is also provided with a central threaded recess 90 facing the flapper 84. The central shaft 40 is provided with external threads 91 so that the plunger 83 may be threaded into the end of the central shaft 40. Thus, it will be seen that the plunger 83 is rigidly connected to the central shaft 40 as is the armature 14.

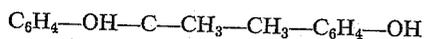
The flapper 84 is of annular disc shape and is co-extensive with the outer portion 92 of the core shell 72 and with the facing surface 93 of the solenoid winding 70. The flapper 84 is provided with a central annular disc or insert 95 which preferably consists of a nonmagnetic or insulating material as shown. The central annular insert 95 may have an outer, central cylindrical projection 96 cooperating with an annular recess 97 in the flapper 84 so that the flapper 84 and the annular insert 95 may be securely connected.

The annular insert 95 has a central opening 98 through which the shaft 40 extends. Keyed to the shaft 40 is a disc 100 disposed in an annular recess 101 in the insert 95. The recess 101 is open toward the plunger 83. Thus, it will be seen that when the flapper 84 moves toward the left as shown in FIG. 4, it will force the shaft 40 to move along with the flapper. On the other hand, the plunger 83 is free to continue the leftward movement because the disc 100 will move out of its recess 101 thus permitting further travel of the plunger 83 and shaft 40 even after the flapper 84 abuts the solenoid surface 93.

As will be explained more fully hereinafter, the distance between the opposing surface 93 of the solenoid winding 70 and the surface 103 of the flapper 84 is much less than the distance the plunger 83 has to travel until it abuts the central core shell portion 78. The purpose of this arrangement will be explained hereinafter.

The shell 72 is preferably disposed in a cup shape shell 105 which consists of a nonmagnetic material.

Before describing in detail the operation of the relay illustrated in the drawings, it will be convenient at this time to describe the preferred materials of which the relay is made. Thus, the main housing 10 and the end caps 11 and 12 may be made from an insulating plastic material such, for example, as a polycarbonate. A polycarbonate is a polymer derived from bisphenol A or 4,4' dihydroxy diphenyl propane. This compound has the chemical formula



Such a polycarbonate is sold in the trade under the name of Lexan by General Electric Company. This plastic material may readily be molded and can be cheaply made in mass production. It is also characterized by great impact strength.

The two housing portions 20 and 21 may be joined together by a suitable cement, by heat sealing or in any other expedient manner. Lexan permits also to join the two housing portions by applying a solvent to the surfaces to be joined. The two housing portions may then be put together and are joined when the solvent dries.

Preferably, the brush holder 54 is also made of Lexan. Similarly, the three brush holder portions 55, 56 and 57 may be joined together in the manner previously outlined. Also, the switch armature 14 preferably consists of Lexan.

It is also preferred to provide a coating 106 over the exposed surface 93 of the solenoid winding 70 and the corresponding exposed surface of the core shell 72. To this end, the Lexan may be dissolved in a suitable solvent and a layer applied which may be one or two mils thick after it has dried. The advantage of this Lexan coating 106 is its great impact strength which will withstand the impact of the flapper 84. In addition, the Lexan coating

93 breaks up the residual magnetic flux or magnetic circuit which may exist after the solenoid has been deenergized. It also reduces the shock of the impact which might cause deterioration of the desired magnetic hysteresis curve.

The conical detent 31 may also be made of Lexan. Preferably, however, the conical detent 31 is made of self-lubricating material. Such a material is sold in the trade under the name of Nylotron GS. Nylotron GS is compounded together with nylon and a suitable lubricant such as graphite or molybdenum disulphide. Nylotron GS is a plastic material which can be readily molded and which is self-lubricating to reduce wear.

Preferably, the plunger 83 is guided and lubricated by a guide tube 107 disposed in the cylindrical recess 71 of the solenoid winding 70 and adjacent the inner core shell portion 78. Preferably, the plunger guide tube 107 is also made of Nylotron GS so as to lubricate the plunger and reduce wear. Alternatively, the guide tube 107 may be made of Teflon or any other suitable material.

The shell 106 is preferably made of brass or some other nonmagnetic material serving the purpose to confine the magnetic lines or flux. Both core shell portions 72 and 74 may be molded or sintered from powdered iron. Alternatively, they may be made from a magnetizable iron such as Armco ingot iron. The main shaft 40 may, for example, consist of brass.

The various shorting brushes 45 through 48 may consist of any conducting material which has a flaking action under wear. Thus, the shorting brushes may be made of or may have their central projections 63 plated with an alloy known as coin silver which consists of 92% silver and 8% copper. Alternatively, the shorting brushes may consist of or be plated with an alloy known as nickel silver which includes 81% copper and 18% nickel. The shorting brushes may also consist of palladium, rhodium, platinum or gold or may be plated therewith. All these metals have the property that they are resistant to chemical action and hence the contact surface tends to remain clean. They also have a flaking action which further helps to maintain a clean contact surface.

The contacts 43 and 44 may be made of any metal which has pits or depressions. Thus, the contacts may consist of or be plated with molybdenum. Alternatively, tungsten or stainless steel may be used which also provide a pitted surface. It is also feasible to make the contacts of copper or brass which is nickel plated.

The operation of the relay illustrated in the drawings will now be apparent. Let it be assumed that the relay is originally in the position shown in FIG. 1. Subsequently, the solenoid winding of the solenoid 15 may be energized. Thereupon, the flapper 84 and the plunger 83 will be attracted to move the armature 14 from the right to the left into the position shown in FIG. 2. As a result, an electric circuit connected between the brushes 45 and 46 will be opened. At the same time, an electric circuit connected between the brushes 46 and 47 will be closed. The same operation takes place with the second set of three shorting brushes.

This has been schematically illustrated in FIG. 6, which illustrates the position of the switches corresponding to the relay position of FIG. 1. Thus, an electric circuit connected to the brushes 45 and 46 is closed while that between brushes 46 and 47 is opened. It will be understood that electric conductors connect each of the six brushes with one of the six screws 26. Two of the screws 26 interconnect respectively the windings of solenoids 15 and 16 to permit sequential energization thereof.

Considering in greater detail the operation of the solenoid of the invention. Referring now to FIG. 4, when the solenoid winding 70 becomes energized, the flapper 84 is attracted primarily by the solenoid winding 70 and secondarily by the core shell portion 73. Since the distance between the flapper 84 and the solenoid winding is relatively short, the flapper is attracted with a relatively large force. This force is sufficient to move the conical

detent 31 from its recess 68 onto the flat surface 66 of the switch armature 14.

By way of example, it may be assumed that the spring 30 presses the conical detent 31 downwards with a force of 14.2 pounds. It may also be assumed that the angle of the conical depression 67 or 68 amounts to 45° while the angle of the conical tip 64 of the detent may amount to 40°. Thus, it can be calculated that the conical detent 31 may be moved to the right or to the left out of either of its conical recesses with a force of 10.2 pounds. It will be noted that, due to the difference of the angles of the conical recesses 67 or 68 and of the conical tip 64 of the detent, the detent essentially has a line contact with its recess. This obviously facilitates moving the detent out of its recess.

It may also be assumed that the width of the conical recess 67 or 68 is 0.015 inch or 15 mils. At the same time, it may be assumed that the distance between the edges of the two recesses is 0.075 inch. Thus, the detent must travel 0.090 inch from conical recess 67 to recess 68 or vice versa. The travel of flapper 84 under these assumptions may, for example, amount to 9 mils. This distance is sufficient to move the conical detent 31 out of its recess until its flat tip 65 fully engages the flat surface 66 as shown in FIG. 5. On the other hand, the travel of the flapper 84 may amount to 0.090 inch, that is, the entire travel necessary to move the detent from one recess to the other.

It may further be assumed that the coefficient of friction between the Lexan surface 66 of the switch armature 14 and the Nylotron surface of the flat tip 65 of the detent amounts to 0.01. Since the weight acting on the detent is 14.2 pounds, a force of 0.01 times 14.2 or 0.142 pounds corresponding to 2¼ ounces is needed to move the armature 14 once the detent 31 rides over the flat surface 66.

These calculations show that the initial pull exerted by the solenoid for a distance of 0.009 inch must amount to 10.2 pounds. For the remainder of the travel of 0.090 inch, a force slightly in excess of 2¼ ounces is sufficient to move the armature from one position to the other. In other words, this is the small force required of the plunger 83.

The insert 95 of the flapper 84 is preferably made of a nonmagnetic material such, for example, as Lexan. The purpose of this is that there will be no magnetic force tending to pull the plunger 83 toward the right of FIG. 4.

It may be noted that the magnetic field after the solenoid winding has been energized requires a certain amount of time to build up. Until the full magnetic field has been built up, the solenoid armature will not move because it has to overcome a relatively large force. Once the magnetic field has been built up to its full strength, the movement will be very rapid until eventually the flapper 84 hits the Lexan coating 106. Thereafter, the plunger 87 is attracted by the magnetic field existing in the interior 71 of the winding which is assisted by the central core shell 74. The stepped cylindrical shape of the plunger 83 is for the purpose of increasing the surface, thereby to intercept a large number of magnetic flux lines by the plunger. Thus, the plunger 83 will pull the switch armature through the major portion of its travel but with a very small force which is sufficient to move the armature until the detent again locks it.

It may be noted that the solenoid winding 70 may, for example, have a resistance of 500 ohms and may be energized with a voltage of 20 volts. Thus, 0.04 ampere or 40 milliamperes will flow in the coil. The total power consumption is accordingly 0.8 watt.

It may be noted that the spring 30 through the detent 31 exerts a large force on the armature 14. This force is taken up by the central shaft 40 and is distributed by the respective plungers 83 onto their guide tubes 107. Since the guide tubes 107 are preferably self-lubricating, there will be little frictional resistance.

The solenoid of the invention can readily overcome a force of acceleration of the order of 100 g, where g is the acceleration of the gravitational field of the earth. Assuming that the movable armature has a total weight of 1.6 ounces or less: With an acceleration of 100 g, this weight would be 10 pounds which is still less than the weight required to pull the detent cone 31 out of its recess. Obviously, the armature weight could be made smaller or the spring force larger so that the resulting device can be designed to withstand a higher acceleration if needed.

The relay may be assembled in the following manner:

At first, the armature 14 is secured to the central shaft 40 by the two snap discs 41. Then, the snap ring 100 is put on the shaft after the flapper 84 with its central insert 95 has been put between the plunger and the armature. Subsequently, the two plungers are screwed on the ends of the shaft 40. Thereafter, the various shorting brushes with their springs are inserted into their pockets 60. The two solenoids 15 and 16 with their shells 105 are assembled in their respective end caps 11 and 12. Now, the three brush holder portions 55, 56 and 57 are assembled about the armature. Then, the conical detent 31 with its spring 30 is inserted into the main housing 10 which may now be assembled about the brush holder. Subsequently, the two end caps are put over the main housing and secured thereto. The relay is now ready for operation.

While the solenoid of the invention has been explained in connection with a latching relay, it will be understood that the solenoid of the invention may also be used for other applications with or without a detent mechanism. For example, the solenoid of the present invention may be used in connection with a fluid valve which requires a large initial force for opening the valve against the force of fluid pressure.

There has thus been disclosed a solenoid which will develop a relatively large force during the initial travel of its armature and thereafter a relatively small force. Such a solenoid may be used, for example, in connection with a latching relay designed to withstand large forces of acceleration or in connection with fluid valves. The solenoid can be designed of relatively light weight and requires a relatively small electric energy for its operation. Both of these factors are of prime importance for air-borne applications or for satellites where both electric power and weight are at a premium. This is accomplished by making the armature of two portions, one of which develops the initial large force while the other is designed to move the armature through the bulk of its travel against a low frictional resistance.

The invention and its attendant advantages will be understood from the foregoing description. It will be apparent that various changes may be made in the form, construction and arrangement of the parts of the invention without departing from the spirit and scope thereof or sacrificing its material advantages, the arrangement hereinbefore described being merely by way of example. I do not wish to be restricted to the specific form shown or uses mentioned except as defined in the accompanying claims, wherein various portions have been separated for clarity of reading and not for emphasis.

I claim:

1. A solenoid providing, when energized, a relatively large force during the initial portion of movement of its armature and a relatively small force during the remaining portion of movement of its armature to overcome an initial large resistance to the armature movement, said solenoid comprising:

- (a) a single solenoid having a winding adapted to be energized and of cylindrical shape providing a hollow interior space and having at least one flat surface;
- (b) a movable armature for said solenoid and adapted to be attracted by said solenoid winding when said winding is energized, said armature including

- (1) a disc-shaped flapper disposed adjacent one of the flat surfaces of said winding and adapted to be attracted thereby for providing the initial large force, said flapper being spaced a relatively small distance from said solenoid, said armature further including 5
- (2) a plunger mechanically coupled to said flapper, said plunger being disposed in the interior space of said solenoid and adapted to be attracted thereby, said plunger providing the relatively small force. 10

2. A solenoid providing, after energization, a relatively large force during the first small portion of movement of its armature and thereafter a relatively small force to overcome an initial large resistance to the movement of its armature, said solenoid comprising: 15

- (a) a single solenoid having a winding adapted to be energized and forming a hollow cylinder providing a hollow central space and having at least one flat surface; 20
- (b) a flapper of magnetizable material disposed adjacent one of the flat faces of said winding, and said flapper being adapted to be attracted by said solenoid winding upon energization thereof with a relatively large force; 25
- (c) a shaft secured to said flapper in such a manner that said shaft is pulled by said flapper upon energization of said winding but is permitted to continue moving in the same direction after said flapper abuts said winding; and 30
- (d) a plunger of magnetizable material secured to said shaft, said flapper and said plunger forming together the armature of said solenoid, said plunger being disposed in said hollow space and being adapted to be attracted by said winding upon energization thereof, said plunger having a movement which is appreciably larger than that of said flapper, the force exerted by said plunger being relatively small compared to that exerted by said flapper. 35

3. A solenoid providing, when energized, a relatively large force during the initial portion of movement of its armature and a relatively small force during the remaining relatively large portion of movement of its armature to overcome an initial large resistance to the armature movement, said solenoid comprising: 40

- (a) a single solenoid having a winding adapted to be energized and of cylindrical shape providing a hollow interior space and having two opposed flat surfaces; 45
- (b) a core shell surrounding the cylindrical surface of said winding, one flat surface thereof and extending partially into the interior space thereof; 50
- (c) a movable armature for said solenoid and adapted to be attracted by said solenoid winding and core shell when said winding is energized, said armature including 55

- (1) a disc-shaped flapper disposed adjacent the free flat surface of said winding and adapted to be attracted thereby for providing the initial large force, said flapper being spaced a relatively small distance from said solenoid, and said armature further including 60
- (2) a plunger mechanically coupled to said flapper, said plunger being disposed in the interior space of said solenoid and adapted to be attracted by said core shell, said plunger being spaced from said core shell a relatively large distance for providing the relatively small force over a relatively large distance, and said flapper having a relatively large air gap with said plunger. 70

4. A solenoid providing, after energization, a relatively large force during its first portion of movement and thereafter a relatively small force to overcome an 75

initial large resistance to the movement of its armature, said solenoid comprising:

- (a) a single solenoid having a winding adapted to be energized and forming a hollow cylinder to provide a hollow central space and having two opposed flat surfaces;
- (b) a core shell of magnetizable material surrounding the cylindrical surface and one flat face of said winding, said shell having a portion disposed in the hollow space of said winding;
- (c) a cup-shaped member of nonmagnetizable material surrounding said winding and said shell to confine the magnetic flux;
- (d) a flapper of magnetizable material disposed adjacent the other flat face of said winding, said flapper being adapted to be attracted by said solenoid winding upon energization thereof with a relatively large force;
- (e) a shaft secured to said flapper in such a manner that said shaft is pulled by said flapper upon energization of said winding but is permitted to continue moving in the same direction after said flapper abuts said winding; and
- (f) a plunger of magnetizable material secured to said shaft, said flapper and said plunger forming together the armature of said solenoid, said plunger being normally spaced from said shell portion and being disposed in said hollow space and being adapted to be attracted thereby upon energization of said winding, said plunger having a movement which is appreciably larger than that of said flapper before engagement with said shell and winding, respectively, the force exerted by said plunger being relatively small compared to that exerted by said flapper.

5. A solenoid providing, when energized, a relatively large force during the initial small portion of movement of its armature and a relatively small force during the remaining relatively large portion of movement of its armature to overcome an initial large resistance to the armature movement, said solenoid comprising:

- (a) a single solenoid having a winding adapted to be energized and of cylindrical shape providing a hollow interior space and having two opposed flat surfaces;
- (b) a core shell surrounding the cylindrical surface of said winding, one flat surface thereof and extending partially into the interior space thereof, said shell portion disposed in said interior space having a central recess forming a conical tip followed by a plurality of cylindrical spaces of successively larger diameter toward its outer end;
- (c) a movable armature for said solenoid and adapted to be attracted by said solenoid winding and core shell when said winding is energized said armature including

- (1) a disc-shaped flapper disposed adjacent the free flat surface of said winding for providing the initial large force, said flapper being spaced a relatively small distance from said solenoid and being adapted to be attracted thereby, and said armature further including
- (2) a plunger mechanically coupled to said flapper, said plunger being disposed in the interior space of said solenoid and having a shape to fit snugly the central recess of said shell portion and being adapted to be attracted by said core shell, said plunger being spaced from said core shell a relatively large distance for providing the relatively small force over a relatively large distance.

6. A solenoid providing, after energization, a relatively large force during its first portion of movement and thereafter a relatively small force to overcome an initial

large resistance to the movement of its armature, said solenoid comprising:

- (a) a solenoid having a winding adapted to be energized and forming a hollow cylinder to provide a hollow central space and having two opposed flat surfaces; 5
- (b) a core shell of magnetizable material surrounding the cylindrical surface and one flat face of said winding, said shell having a portion disposed in the hollow space of said winding;
- (c) an annular flapper of magnetizable material disposed adjacent the other flat face of said winding and coextensive with said winding and outer core shell, said flapper being adapted to be attracted by said solenoid winding upon energization thereof with a relatively large force; 10 15
- (d) a shaft;
- (e) an annular insert of nonmagnetizable material secured to said flapper and disposed about said shaft, said insert having an open recess facing said hollow space of said winding; 20
- (f) a disc secured to said shaft and abutting against said recess in said insert to pull said shaft upon attraction of said flapper and permitting said shaft to continue moving in the same direction after said flapper abuts said winding; and 25
- (g) a plunger of magnetizable material secured to said shaft, said flapper and said plunger forming together the armature of said solenoid, said plunger being normally spaced from said shell portion and being disposed in said hollow space and being adapted to attract thereby upon energization of said winding, said plunger having a movement which is appreciably larger than that of said flapper before engagement with said shell and winding, respectively, the force exerted by said plunger being relatively small compared to that exerted by said flapper. 30 35

7. A double solenoid and associated detent mechanism comprising:

- (a) a first and a second solenoid spaced from each other, each solenoid including 40
 - (1) a single solenoid winding adapted to be energized and forming a hollow cylinder to provide a hollow central space and having two opposed flat surfaces;
 - (2) a core shell of magnetizable material surrounding the cylindrical surface and one flat face of said winding, said shell having a portion disposed in the hollow space of said winding; 45
 - (3) an annular flapper of magnetizable material disposed adjacent the other flat face of said winding, said flapper being adapted to be attracted by said solenoid winding upon energization thereof with a relatively large force; 50
 - (4) a plunger of magnetizable material, said flapper and said plunger forming together the armature of said solenoid, said plunger being normally spaced from said shell portion and disposed in said hollow space and being adapted to be attracted thereby upon energization of said winding, said plunger having a movement which is appreciably larger than that of said flapper before engagement with said shell and winding, respectively, the force exerted by said plunger being relatively small compared to that exerted by said flapper; 55 60 65
- (b) a common shaft secured to said plungers and to said flappers in such a manner that said shaft is pulled by one of said flappers upon energization of its winding but is permitted to continue moving in the same direction after said flapper abuts its winding; and 70
- (c) a detent mechanism coupled to said shaft for locking said shaft in one of two positions after energization of one of said solenoids. 75

8. A double solenoid and associated detent mechanism comprising:

- (a) a first and a second solenoid spaced from each other, each solenoid including
 - (1) a single solenoid winding adapted to be energized and forming a hollow cylinder to provide a hollow central space and having two opposed flat surfaces;
 - (2) a core shell of magnetizable material surrounding the cylindrical surface and one flat face of said winding, said shell having a portion disposed in the hollow space of said winding;
 - (3) an annular flapper of magnetizable material disposed adjacent the other flat face of said winding, said flapper being adapted to be attracted by said solenoid winding upon energization thereof with a relatively large force;
 - (4) a plunger of magnetizable material, said flapper and said plunger forming together the armature of said solenoid, said plunger being normally spaced from said shell portion and disposed in said hollow space and being adapted to be attracted thereby upon energization of said winding, said plunger having a movement which is appreciably larger than that of said flapper before engagement with said shell and winding, respectively, the force exerted by said plunger being relatively small compared to that exerted by said flapper;
 - (b) a common shaft secured to said plungers and to said flappers in such a manner that said shaft is pulled by one of said flappers upon energization of its winding but is permitted to continue moving in the same direction after said flapper abuts its winding;
 - (c) an element secured to said shaft and having a flat surface and two spaced conical recesses;
 - (d) a detent member disposed stationary with respect to said element and having a conical end portion and a flat tip adapted to move over said flat surface upon sequential energization of said solenoids, said conical end portion being adapted to seat in one or the other of said conical recesses; and
 - (e) spring means for urging said detent member against said flat surface and said recesses with an appreciable force.
9. A double solenoid and associated detent mechanism comprising:
- (a) a first and a second solenoid spaced from each other, each solenoid including
 - (1) a solenoid winding adapted to be energized and forming a hollow cylinder to provide a hollow central space and having two opposed flat surfaces;
 - (2) a core shell of magnetizable material surrounding the cylindrical surface and one flat face of said winding, said shell having a portion disposed in the hollow space of said winding;
 - (3) an annular flapper of magnetizable material disposed adjacent the other flat face of said winding, said flapper being adapted to be attracted by said solenoid winding upon energization thereof with a relatively large force;
 - (4) a plunger of magnetizable material, said flapper and said plunger forming together the armature of said solenoid, said plunger being normally spaced from said shell portion and disposed in said hollow space and being adapted to be attracted thereby upon energization of said winding, said plunger having a movement which is appreciably larger than that of said flapper before engagement with said shell and winding, respectively, the force exerted by said plunger being relatively small compared to that exerted by said flapper;

- (b) a common shaft secured to said plungers and to said flappers in such a manner that said shaft is pulled by one of said flappers upon energization of its winding but is permitted to continue moving in the same direction after said flapper abuts its winding; 5
- (c) an element secured to said shaft and having a flat surface and two spaced conical recesses;
- (d) a detent member disposed stationary with respect to said element and having a conical end portion and a flat tip adapted to move over said flat surface upon sequential energization of said solenoids, said conical end portion being adapted to seat in one or the other of said conical recesses, the angle of the cone of said conical end portion being less than the angle of said conical recesses, whereby said detent member has substantially a line contact with said recesses; and 10 15
- (e) spring means for urging said detent member against said flat surface and said recesses with an appreciable force. 20

10. A double solenoid and associated detent mechanism comprising:

- (a) a first and a second solenoid spaced from each other, each solenoid including
 - (1) a solenoid winding adapted to be energized and forming a hollow cylinder to provide a hollow central space and having two opposed flat surfaces; 25
 - (2) a core shell of magnetizable material surrounding the cylindrical surface and one flat face of said winding, said shell having a portion disposed in the hollow space of said winding; 30
 - (3) an annular flapper of magnetizable material disposed adjacent the other flat face of said winding, said flapper being adapted to be attracted by said solenoid winding upon energization thereof with a relatively large force; 35
 - (4) a plunger of magnetizable material, said flapper and said plunger forming together the armature of said solenoid, said plunger being 40

normally spaced from said shell portion and disposed in said hollow space and being adapted to be attracted thereby upon energization of said winding, said plunger having a movement which is appreciably larger than that of said flapper before engagement with said shell and winding, respectively, the force exerted by said plunger being relatively small compared to that exerted by said flapper;

- (b) a common shaft secured to said plungers and to said flappers in such a manner that said shaft is pulled by one of said flappers upon energization of its winding but is permitted to continue moving in the same direction after said flapper abuts its winding;
- (c) an element secured to said shaft and having a flat surface and two spaced conical recesses;
- (d) a detent member disposed stationary with respect to said element and having a conical end portion and a flat tip adapted to move over said flat surface upon sequential energization of said solenoids, said conical end portion being adapted to seat in one or the other of said conical recesses;
- (e) spring means for urging said detent member against said flat surface and said recesses with an appreciable force; and
- (f) a guide tube for each of said plungers disposed in said hollow central space of said winding, said guide tubes providing a low-friction bearing for said plungers, said plungers and guide tubes taking up the force exerted by said spring means.

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