United States Patent [19]

Tada

[11] **3,713,059**

[45] **Jan. 23, 1973**

[54] **SOLENOID OPERATED PLUNGER DEVICE**

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[22] Filed: **Dec. 1, 1971**

[21] Appl. No.: **203,653**

[30] **Foreign Application Priority Data**

Dec. 5, 1970 Japan 45/121838

[52] **U.S. Cl.** **335/259,** 335/264

[51] **Int. Cl.** **H01f 7/08**

[58] **Field of Search** 335/257, 259, 264, 265, 279

[56] **References Cited**

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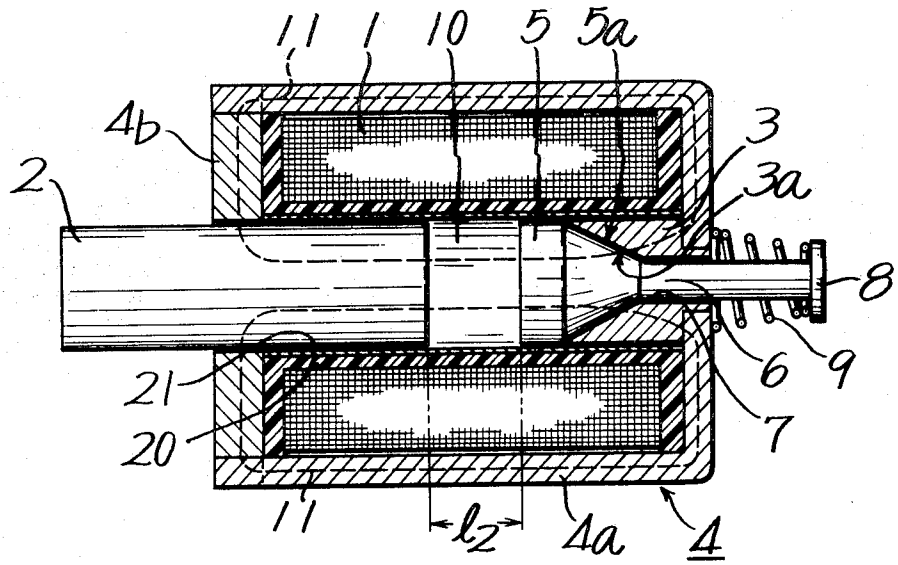
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Primary Examiner—George Harris
Attorney—William D. Hall et al.

[57] **ABSTRACT**

A solenoid operated plunger device is provided of the type in which a plunger is arranged to be forced by magnetic attraction into a coil upon energization thereof. Movably interposed between the plunger and a socket therefor is an auxiliary magnetic body. A guide rod of magnetic material attached to one end of the auxiliary magnetic body extends through the socket to the exterior thereof, and a spring engages the externally projecting part, the spring urging the auxiliary magnetic body against the socket. Upon energization of the coil, the auxiliary magnetic body against the socket. Upon energization of the coil, the auxiliary magnetic body is initially driven toward the plunger, and when it abuts against the plunger, both are integrally driven to the socket. The socket and the auxiliary magnetic body have concave and convex surfaces, respectively, which can fit each other, thereby increasing the area of contact therebetween.

3 Claims, 5 Drawing Figures



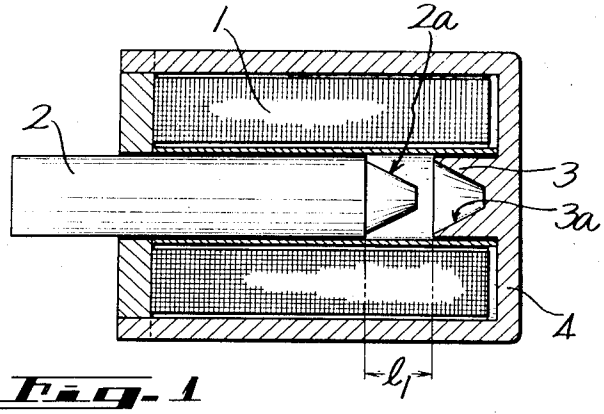

1
2a
2
3
3a
4
l_1

Fig. 1

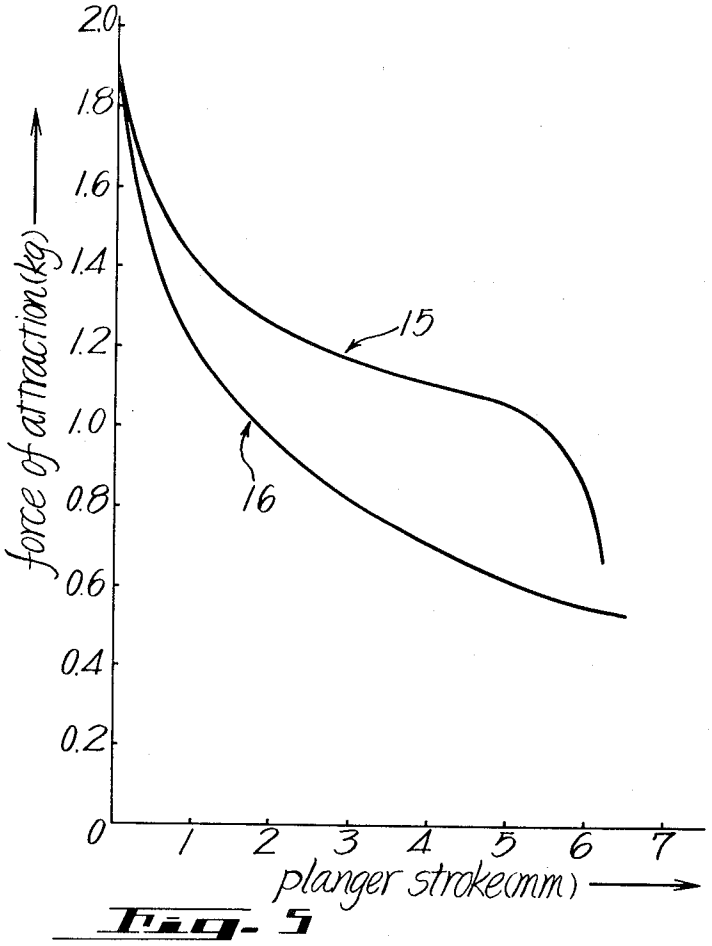

force of attraction (kg)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
plunger stroke (mm)
15
16

Fig. 5

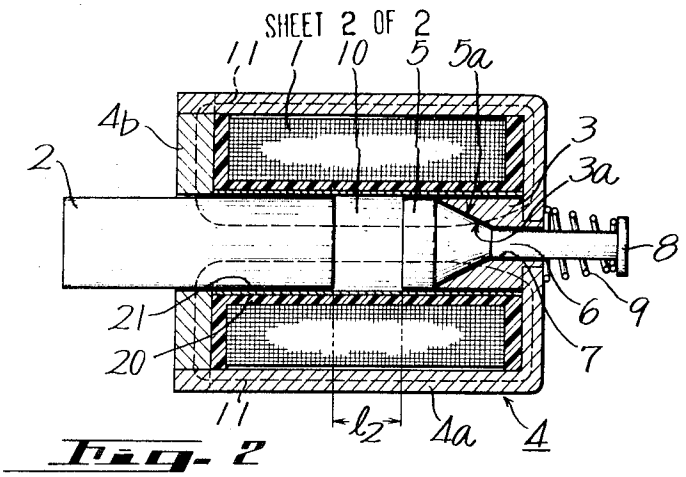


Fig. 2

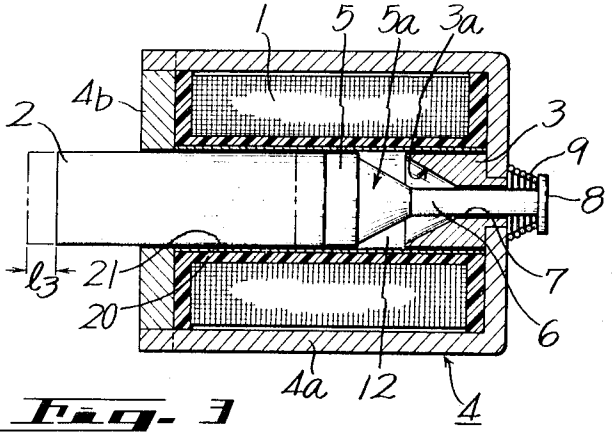


Fig. 3

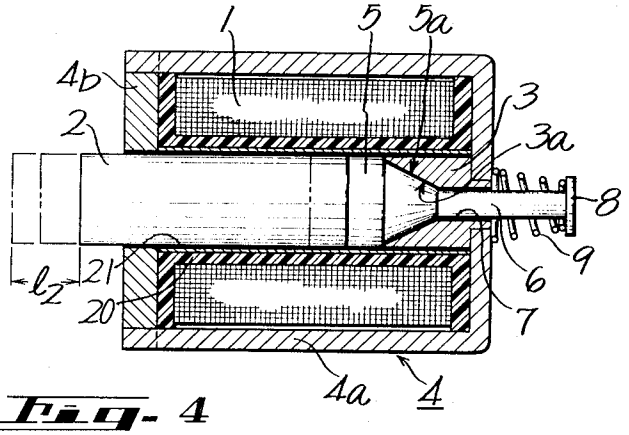


Fig. 4

SOLENOID OPERATED PLUNGER DEVICE

BACKGROUND OF THE INVENTION

The invention relates to a d.c. excited, solenoid operated plunger device, in particular, to a solenoid operated plunger device having an increased plunger stroke, that is, an increase in the distance travelled by the plunger, or having an increased speed of operation.

Solenoid operated plunger devices of the kind described heretofore had a limited plunger stroke insufficient to assure positive control of other associated apparatus with such plunger motion. Alternately where the plunger stroke is increased, the speed at which the plunger can be operated had to be reduced substantially, thereby rendering such plunger device unsatisfactory for use with apparatus requiring rapid control.

Therefore, it is an object of the invention to provide a solenoid operated plunger device having an increased plunger stoke or an increased speed of operation.

SUMMARY OF THE INVENTION

In accordance with the invention, an auxiliary magnetic body is interposed between the plunger and the socket so as to be movable therebetween. One end of the auxiliary magnetic body projects externally by way of a magnetic guide rod extending through a guide aperture formed in the socket. A spring is interposed between the projecting guide rod and the stationary part or magnetic yoke. In the non-excited condition of the device, the resilience of the spring causes the auxiliary magnetic body to abut against the socket, thereby creating an air gap between the plunger and the auxiliary magnetic body. The socket and the auxiliary magnetic body have their opposing end faces formed concave and convex, respectively, so as to permit interfitting, as was described before.

Upon energization of the novel device, the auxiliary magnetic body is initially driven toward the plunger against the resilience of the spring, by virtue of a force of attraction acting therebetween. As the magnetic body and the plunger come close to each other, the force of attraction therebetween increases markedly to cause the plunger to commence its movement toward the auxiliary magnetic body into abutting engagement with the latter. Under this situation, the magnetic guide rod is saturated magnetically. Both plunger and auxiliary magnetic body act as a unit magnetically, and the force of attraction between the auxiliary magnetic body and the socket together with the resilience of the spring causes both the plunger and the auxiliary magnetic body to be strongly urged toward the socket until they abut against the latter. It will be appreciated that because of the interfitting concave and covex configurations of the opposing faces of the socket and the auxiliary magnetic body to present a considerable amount of opposite surface area, the force of attraction acting therebetween is sufficient to assure the abutting engagement thereof, despite the presence of the magnetic guide rod.

A BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic section of a solenoid operated plunger device of the prior art,

FIG. 2 is a schematic section of an embodiment of the solenoid operated plunger device according to the invention,

FIGS. 3 and 4 are similar views to FIG. 2, showing the plunger at different positions to illustrate the operation of the device, and

FIG. 5 is a graph plotting the force of attraction against the plunger stroke.

DETAILED DESCRIPTION OF THE INVENTION

Referring first to FIG. 1 for explaining a solenoid operated plunger device of the prior art, typically it comprises a cylindrical solenoid **1** in which a plunger **2** is received so as to be freely movable into and out of the solenoid **1**. The plunger **2** projects externally of the solenoid **1** at one end, and there is provided a socket **3** on the opposite side of the plunger **2**. The socket **3** is connected with a magnetic yoke **4** which extends along the outer periphery of the solenoid **1** and terminates in a radial extension around the projecting end of the plunger **2**. The opposing surfaces of the plunger **2** and the socket **3** are formed as interfitting convex and concave configurations of increased area in order to increase the force of attraction acting therebetween. In the example shown, the end of the plunger **2** opposite the socket **3** is in the form of a truncated cone **2***a*, while the opposing end face of the socket **3** is formed with a frusto-conical recess **3***a* which is a close fit with the end **2***a*.

With such a prior art construction of solenoid operated plunger device, the distance travelled by the plunger **2**, that is, the length of the plunger stroke, is determined by the distance 1_1 indicated in the drawing between the plunger **2** and the socket **3**, and this distance could not have been made long and was on the order of 5 mm at most. In addition, the force of attraction was low and the operation of the plunger slow.

FIG. **2** shows an embodiment of the solenoid operated plunger device according to the invention. In this Figure, the magnetic yoke **4** comprises a U-shaped body **4***a* of magnetic plate, and an end plate **4***b* of magnetic material bridging across and secured to the both limbs of the body **4***a*. A bobbin **20** is arranged between the base of the body **4***a* and the end plate **4***b* with its flanges on opposite ends held against them. The coil **1** is wound on the bobbin **20**, and a thin-walled sleeve **21** of non-magnetic metal such as brass is fitted within the bobbin **20** in contact with the inner periphery thereof. An opening is formed centrally within the end plate **4***b* of the magnetic yoke **4** for receiving the plunger **2** within the sleeve **21**. The socket **3** is mounted on the base of the body **4***a* so as to extend into the sleeve **21**.

In accordance with the invention, an auxiliary magnetic body **5** is interposed between the plunger **2** and the socket **3**, and is formed of the same material as the plunger **2** so as to be substantially commensurate in section with the latter. At its end opposite the socket **3**, the auxiliary magnetic body **5** has a frusto-conical end **5***a* for fitting within a frusto-conical recess **3***a* formed in the end face of the socket **3**.

A thin guide rod **6** of magnetic material extends axially from the end of the auxiliary magnetic body **5** adjacent the socket **3** at a central position. The guide rod **6** extends externally of the magnetic yoke **4** by passing through a guide aperture **7** formed concentrically

within the socket 3. The projecting end of the guide rod 6 is provided with an abutment 8, and a helical spring 9 is disposed around the guide rod 6 between the abutment 8 and the magnetic yoke 4. Normally or in the inoperative condition when the solenoid 1 is not energized, the socket 3 and the auxiliary magnetic body 5 have their opposing faces 3*a* and 5*a* in contact with each other, thereby leaving a space 10 of length 1_2 between the auxiliary magnetic body 5 and the plunger 2. The guide rod 6 is designed to be saturated magnetically when the coil 1 is energized and the auxiliary magnetic body 5 comes into contact with the adjacent end face of the plunger 2 to thereby leave an air gap between the auxiliary magnetic body 5 and the socket 3.

In operation of the device of the invention, when the solenoid 1 is energized, a magnetic circuit is completed through the plunger 2, auxiliary magnetic body 5, socket 3 and magnetic yoke 4, as indicated by broken lines 11. A force of attraction is developed across the plunger 2 and the auxiliary magnetic body 5 so as to minimize the reluctance of the magnetic circuit. Because the plunger 2 is greater in size and weight than the auxiliary magnetic body 5, the latter moves initially under the action of attraction, the movement overcoming the resilience of the helical spring 9, which is therefore compressed. As the auxiliary magnetic body 5 comes close to the plunger 2, the force of attraction therebetween increases markedly, whereby the plunger 2 also commences to move toward the auxiliary magnetic body 5, abutting the latter with a strong force as shown in FIG. 3. This results in a retraction of the plunger 2 by an amount of 1_3 from its foremost position shown in FIG. 2 and formation of an air gap 12 between the auxiliary magnetic body 5 and socket 3.

At this moment the guide rod 6 is saturated magnetically, so that the air gap 12 will have a maximum reluctance, giving rise to a force of attraction between the auxiliary magnetic body 5 and the socket 3. During this phase of operation, the plunger 2 and the auxiliary magnetic body 5 act as a unit as if they constituted a single plunger. The magnetic force of attraction is added to the resilience of the compressed spring 9, which acts by way of the guide rod 6 to pull the auxiliary magnetic body 5 toward the socket. As a consequence, the plunger 2 and the auxiliary magnetic body 5 are strongly driven into the position abutting against the socket 3 as shown in FIG. 4. Despite the presence of the guide rod 6 which is located in parallel circuit relationship with the path of magnetic reluctance represented by the air gap 12, it is saturated magnetically as mentioned previously, and therefore can no longer act as a by pass across such path. In addition, the increased area of the opposing surfaces of the auxiliary magnetic body 5 and the socket 3 imparted by their convex and concave configurations serves to produce a strong force of attraction.

The auxiliary magnetic body 5 used in the device of the invention is smaller in size and less in weight than the plunger 2, and this facilitates the initial motion of the auxiliary magnetic body 5 under the influence of the force of attraction acting between these members. Because such force of attraction is inversely proportional to the square of the distance involved, it increases to a value, as they come close to each other, sufficient to cause movement of the plunger 2 itself toward the auxiliary magnetic body to reach the position shown in FIG. 3. In this position, the plunger 2 is in the same starting condition as is the plunger of FIG. 1. However, the plunger 2 is retracted by an amount of 1_3, thus reducing the length of the air gap 12 and undergoing an increased amount of attraction as compared with the plunger of FIG. 1. In addition, such force of magnetic attraction is added to the pulling force exerted by the resilience of the spring 9, with the consequence that the total force of attraction to which the plunger of the present device is subjected is far grater than that acting upon the plunge of FIG. 1, thereby operating the plunger more rapidly. Alternatively, where the operating speed may be held at the same level as in the arrangement of FIG. 1, the plunger stroke can be increased. While the presence of guide rod 6 reduces the available force of magnetic attraction between the auxiliary magnetic body 5 and the socket 3, the increased area of their opposing surfaces provided by their convex and concave configurations renders the influence of such reduction negligible. As the thickness of the guide rod 6 is increased, the force of attraction between the plunger 2 and the auxiliary magnetic body 5 increases, while the force available for the motion toward the socket of these members after they have joined is diminished. In order to obtain a longer plunger stroke, the guide rod 6 may be made relatively thick and the resilience of the spring 9 increased. On the other hand, where it is desired to impart a strong force to the plunger, both the thickness of the guide rod 6 and the resilience of the spring 9 may be decreased. In general, the resilience of the spring 9 is chosen slightly less than that required to overcome the force produced upon energization of the coil 1 for driving the auxiliary magnetic body 5 toward the plunger 2.

A specific plunger device was constructed in accordance with FIG. 2. The magnetic yoke 4 measured 29 mm long, 1.6 mm thick and 23 × 26 mm^2 across its end plate. Plunger 2 had a diameter of 8 mm and a length of 34.5 mm. Both conical parts of the socket 3 and the auxiliary magnetic body 5 had a vertical angle of 50°, and the body 5 was 8 mm thick and 3 mm long except the conical part terminating in a guide rod 6, which was 2.5 mm thick. Coil 1 comprised 770 turns of 0.4 mm ϕ copper wire, exhibiting a resistance of 5.5 ohms. The coil 1 was supplied with 10 volts d.c., and the resulting force of attraction is plotted in FIG. 5 on the ordinate against the distance travelled by the plunger on the abscissa. Curve 15 represents the operational characteristic of the above example constructed in accordance with the invention, while curve 16 represents the similar characteristic of a prior art device constructed using the same parameters. It is noted that a reduction in the force of attraction occurs with the present device as with a prior art device, but the reduction is not as abrupt as in curve 16, and the force of attraction is considerably increased with the present device.

Having described the invention, what is claimed is:

1. A solenoid operated plunger device comprising a solenoid coil, a movable plunger disposed within the coil and projecting from one end thereof, a socket disposed at a fixed position within the other end of the coil, a magnetic yoke extending outside the coil and

providing a magnetic interconnection between the plunger and the socket, an auxiliary magnetic body spaced from said plunger and interposed between the plunger and the socket so as to be movable therebetween, a guide rod attached to one end of said auxiliary magnetic body, said guide rod extending through the socket centrally and projecting externally of the magnetic yoke, and a coiled spring disposed on the externally projecting part of the guide rod and urging the guide rod toward the exterior of said yoke, to hold said auxiliary magnetic body in contact with said socket when said coil is not energized, the resilience of said coiled spring being chosen such that, when said coil is energized, the force of attraction urging said auxiliary magnetic body toward said plunger is slightly greater than the oppositely directed force applied to said auxiliary magnetic body by the coiled spring whereby said auxiliary magnetic body initially moves away from said socket toward said plunger to produce an air gap between said auxiliary magnetic body and said socket whereafter said plunger and auxiliary magnetic body, upon coming into contact with one another, move as a unit toward said socket to eliminate the air gap between said auxiliary magnetic body and socket.

2. A solenoid operated plunger device according to claim 1, in which said guide rod comprises a magnetic material, the material and thickness of said guide rod being chosen such that it is saturated magnetically by the flux emanating from the energized coil when said auxiliary magnetic body is in contact with the plunger.

3. The device of claim 1 wherein said socket and said auxiliary magnetic body have interfitting concave and convex opposing surfaces respectively.

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