June 18, 1968 F. SCHROEDER, JR 3,389,355

MULTIPLE COIL SOLENOID

Filed June 5, 1964

FIG. 1.

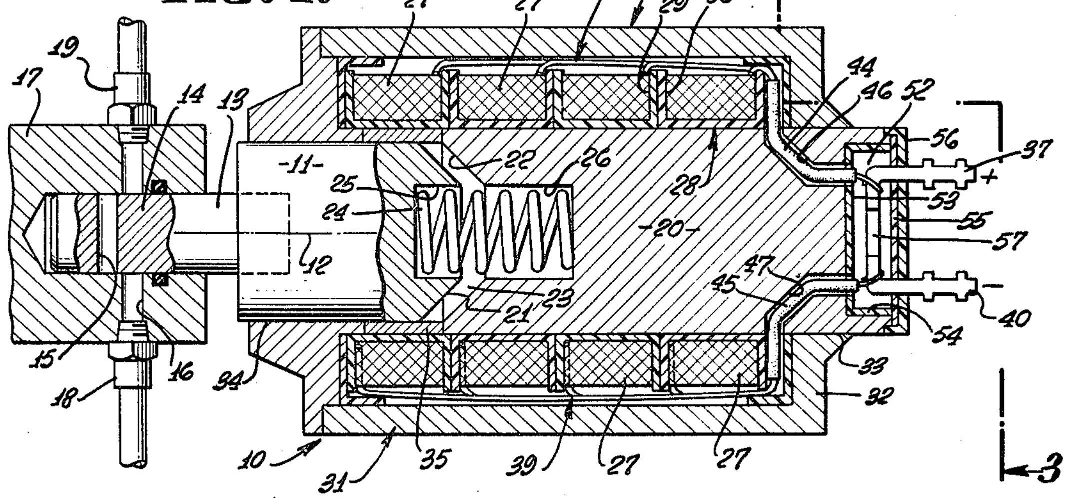


FIG. 2.

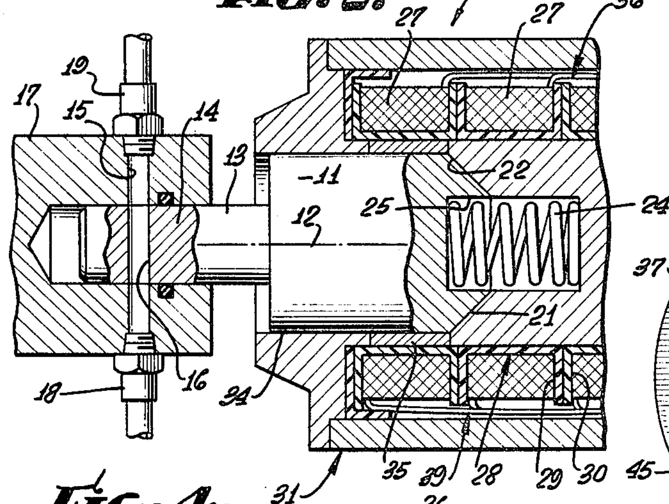


FIG. 3

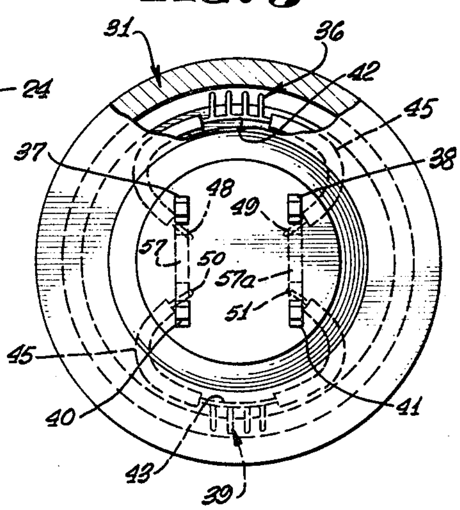
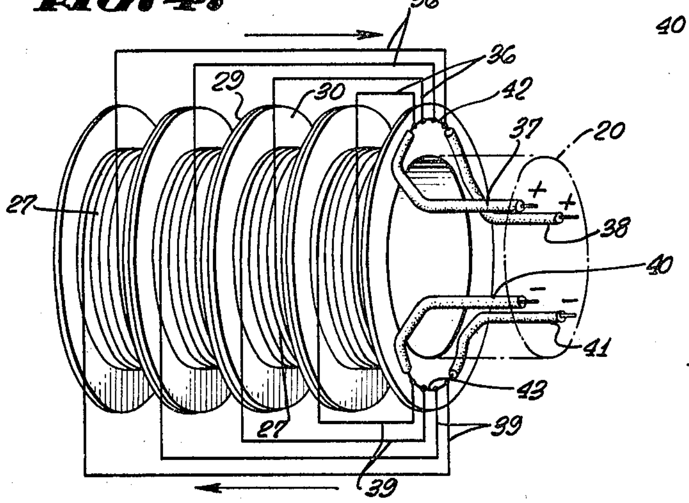


FIG. 4.



INVENTOR.
FRED SCHROEDER, JR.
BY *White & Haefliger*
ATTORNEYS.

United States Patent Office

3,389,355

Patented June 18, 1968

3,389,355

MULTIPLE COIL SOLENOID

Fred Schroeder, Jr., 6614 Valjean St., Van Nuys, Calif. 91906

Filed June 5, 1964, Ser. No. 372,981
11 Claims. (Cl. 335—266)

This invention has to do with improvements in solenoids adapted to operate any of the various types and kinds of devices e.g. mechanical or electrical, responsive to solenoid actuation, and is directed particularly to improvements in solenoid construction which may insure to high performance factors approaching infallibility, continued proper operation of the solenoid notwithstanding the development of defects that would normally prevent such performance.

Such assurance becomes of great necessity and importance where the performance of space object, mechanical or electrical devices or control systems may depend upon proper continued operability of a single solenoid, failure of which may nullify undertakings of great magnitude and expense. Accordingly, my general object is to insure against such failures by novel solenoid construction characterized by its capacity to accept partial impairment and yet remain fully operative for its intended purposes.

Structurally, the invention contemplates provision of a direct succession of a plurality, at least three, of coils about a magnetic metallic core operable to actuate a magnetic plunger against a particular work load or resistance. Preferably, the coils have essentially the same core magnetizing capacity at corresponding applied voltage, and electrical current is supplied to the coils so that all are simultaneously energized and each independently of the others, so that upon failure of one for any reason, the others will remain effective. Thus by placement of all the coils in energizing relation to the core and by design of the coil capacities and their number in relation to the work load, less than all the coils, e.g. in the event of failure of one, can fully satisfy the plunger load requirements. In this manner, assured performance of the solenoid as a whole may be brought to approach practical certainty.

The invention has various additional features and objects, all of which will be more readily and fully understood from the following detailed description of an illustrative embodiment shown by the accompanying drawing, in which:

FIG. 1 is a vertical elevation taken through a preferred solenoid assembly embodiment;

FIG. 2 is a fragmentary vertical elevation of the embodiment seen in FIG. 1 during energization of the solenoid coils;

FIG. 3 is an end elevation, partly broken away, taken on line 3—3 of FIG. 1; and

FIG. 4 is a schematic perspective showing of the solenoid coils, insulator structure therefor and connector means for simultaneously electrically energizing the coils in parallel relation.

Referring first to FIGS. 1–3, the solenoid assembly **10** may be considered to comprise magnetizable means including a plunger **11** movable along the axis designated at **12**. Merely for purposes of illustration, the plunger is shown as connected at **13** to a load **14**, which may for example comprise a valve part having a duct **15** brought into flow passing communication with ducting **16** when the plunger **11** moves into the position shown in FIG. 2. Ducting **16** is formed in valve body **17** to which flow lines are connected at **18** and **19**.

The magnetizable metallic means may also include a core such as is designated at **20**, and toward which the

plunger **11** is displaceable, the core and plunger typically having closely spaced terminals **21** and **22**. The latter may be tapered as shown to provide for more uniform pull or loading exertion as the plunger moves toward the core, the narrow gap between the terminals **21** and **22** being indicated at **23**. In this regard, a return spring **24** may be housed within the plunger and core recesses **25** and **26** in such manner as to return the plunger to the position shown in FIG. 1 when the solenoid is not electrically energized.

The assembly also includes a direct succession of a plurality of coaxial independently conductive coils surrounding the plunger and core, typical coils of this nature being indicated at **27**. They are similar in size in order that they may have the same core magnetizing capacity at corresponding voltage applied to each coil, whereby each coil contributes approximately the same amount of flux to the core and to the plunger operating the work. While four coils are shown, it will be understood that at least three should be used in order that the diminution of total flux passing through the core and plunger as a result of inoperation of one coil may not be excessive. The coils are helically wound with insulated wire, with a number of turns to provide the desired solenoid pull exerted by the plunger.

The assembly as illustrated also includes electrical insulator structure separating the coils from each other and also from the core and plunger iron or magnetizable metal. Typically, the insulator structure comprises separate annular receptacles **28** for the coils and stacked end to end in axial succession with receptacle end flanges **29** and **30** in abutting contact. The receptacles may typically comprise a molded resinous material such as the fluorocarbon tetrafluoroethylene capable of maintaining its desirable physical and electrical insulative properties at relatively high temperature.

The assembly **10** may also be considered to include a magnetizable metallic tubular jacket enclosing the coils and insulator structure. As illustrated, the jacket includes the tubular part **31** having an end flange **32** extending in close annular proximity to the core at **33**. The jacket may also be considered to include the illustrated end cap for part **31**, and which extends in close proximity to the plunger **11** at **34**. Accordingly, a substantially continuous flux path is provided with the flux passing from the core **20** to jacket flange **32**, then along the jacket part **31** to the cap and then to the plunger. From the latter the flux then passes to the core across the gap **23**. A non-magnetic ring **35** is provided to surround the plunger between the cap and the core **20** in order that flux may not be short circuited around the plunger.

Finally, the solenoid assembly includes connector means for simultaneously electrically energizing all of the coils and for effecting coil electrical connection in parallel relation, each coil typically being energized independently of the others. As illustrated, the connector means comprises separate conductors such as are indicated at **36** extending from each of the coils for electrical connection with common terminals **37** and **38** at one end of the core. Also separate conductors **39** are shown extending from each of the coils for electrical connection with common terminals **40** and **41** at the same end of the core. Conductors or leads **36** connect to the outside of the coils and extend between the coils and the jacket part **31** to the bussing connector **42** interconnecting the terminals **37** and **38**. Similarly, conductors or leads **39** run from the inside wires of the coils and between the coils and jacket to the bussing connector **43** joining the common terminals **40** and **41**. Accordingly, not only are the coils connected in parallel relation, but also the positive side of each coil is connected to two positive terminals, as for example **37** and **38**, and the negative side of each coil is connected to two negative terminals **40** and **41**, the recited polarities being reversible. Therefore, should either of terminals **37** and **38** fail, the other will operate to energize the coils and the same is true should either of terminals **40** and **41** fail. This is in addition to the provision for continued and independent operation or energization of the remaining coils should any of them fail, whereby the operation of the solenoid to retract the plunger is made, for all practical purposes, substantially infallible.

It should also be noted from the drawings that the bussing connectors **42** and **43** have insulation coverings **44** and **45** respectively which pass through openings **46** and **47** formed in the end portion of the solenoid core **20**, this construction affording great protection to these connectors. In addition, the connection of the bussing connectors **42** and **43** to the terminal pins at the locations **48**, **49**, **50** and **51** is protected by recessing thereof within the core end portion at **52**, the latter recess being insulatively lined at **53**, **54** and **55**, and capped at **56**. The numeral **57** designates a gap between pins **37** and **40**, there being a similar gap **57***a* between pins **38** and **41**.

A typical solenoid assembly constructed as shown has an overall diameter of 1.3 inches, each coil has 1725 turns of No. 37 insulated wire, and with 11 watts power input at 24 volts DC will produce a plunger pull of between 3 and 20 pounds, and when the dimensions are interrelated in the proportions indicated by the drawings the pull will be approximately 12 pounds.

I claim:

1. A solenoid assembly comprising a magnetic metallic core, a direct succession of a plurality of coaxial independently conductive coils surrounding said core, connector means for simultaneously electrically energizing all of said coils and each independently of the others, said connector means comprising separate conductors extending from common terminals at one end of the core to connections with each of the coils, and a magnetic metallic plunger within the electromagnetic field of said core and coils and displaceable axially thereof in response to energization of all or less than all of said coils.

2. A solenoid assembly according to claim **1**, in which said coils have essentially the same core magnetizing capacity at corresponding applied voltage.

3. A solenoid assembly according to claim **1**, in which said coils are enclosed in a magnetic metallic tubular jacket.

4. A solenoid assembly according to claim **3**, in which said separate conductors extend between the coils and said jacket.

5. A solenoid assembly according to claim **1**, in which said coils are at least three in number and have essentially the same core magnetizing capacity at corresponding applied voltage.

6. A solenoid assembly according to claim **1**, in which said coils or one less than all the coils when electrically energized will displace said plunger against a load resistance of from about 3 to 20 pounds.

7. A solenoid assembly according to claim **6**, in which said coils are four in number and have essentially the same core magnetizing capacity at correspondingly applied voltage.

8. A solenoid assembly according to claim **1**, in combination with work means actuable by said plunger against resistance within the range of about 3 to 20 pounds, and in which all or one less than all of the coils when electrically energized at corresponding voltage will serve to displace the plunger against said resistance.

9. The combination of claim **8**, in which said coils are at least three in number and have essentially the same core magnetizing capacity at correspondingly applied voltage.

10. A solenoid assembly comprising magnetizable metallic means including a plunger, a direct succession of a plurality of generally coaxial independently conductive coils surrounding said magnetizable means, and connector means for simultaneously electrically energizing all of said coils and for effecting coil electrical connection in parallel relation, said connector means comprising separate conductors extending from common terminals at one end of the magnetizable means to connections with each of the coils, the plunger being within the electromagnetic field of said coils and displaceable generally axially thereof in response to energization of all or less than all of said coils.

11. The solenoid assembly of claim **10** including annular electrical insulator structure separating the coils from each other and from said magnetizable means, a magnetizable metallic tubular jacket inclosing said coils and insulator structure and extending in close proximity to said magnetizable means at opposite ends of said succession of coils, and said magnetizable means including a core toward which the plunger is displaceable, the core and plunger having closely spaced terminals.

References Cited

UNITED STATES PATENTS

2,034,272	3/1936	Schroeder	251—137 X
2,450,924	10/1948	Stilwell	317—190
2,457,739	12/1948	Sherrill	251—137 X
3,190,608	6/1965	Hassa	317—190 X

BERNARD A. GILHEANY, *Primary Examiner.*

GEORGE HARRIS, *Examiner.*