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(54) **SOLENOID PUMP WITH ELECTRIC CONTROL MODULE**

MAGNETPUMPE MIT ELEKTRISCHEM STEUERMODUL

POMPE À SOLÉNOÏDE AVEC MODULE DE COMMANDE ÉLECTRIQUE

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(56) References cited:
US-A- 3 742 256 **US-A1- 2002 064 463**
US-A1- 2003 021 693 **US-A1- 2003 175 125**
US-A1- 2007 152 512 **US-A1- 2007 276 544**
US-A1- 2010 037 644 **US-B2- 9 500 190**

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Description

FIELD

[0001] The present disclosure relates to a solenoid pump, and more particularly, to an electronic control module solenoid pump having an externally controlled circuit.

BACKGROUND

[0002] Known solenoid pumps use linear springs to bias a plunger against displacement by a solenoid coil in a pumping cycle. When the springs are fully compressed, the springs occupy an undesirably large space since the coils for the springs stack upon each other. Known control schemes for solenoid pumps use a fixed duty cycle, typically 50, regardless of the magnitude of the input voltage to be used to energize the solenoid coils for the pumps. As a result, too little power is delivered to the coils for low values of the input voltage and the coils remain energized even after plungers for the pumps have fully displaced to fully compress the springs for the pumps. As a result, the pumps consume unnecessarily high amounts of energy and undesirable amounts of heat are generated, which degrades operation of the pumps.

[0003] US Patent Application US 2003/0175125 A1 discloses an operation control method of a reciprocating compressor. The reciprocating compressor using an inverter which is operated at a rated frequency, a current load of the motor is measured, and the measured load is compared with a pre-set reference load. Upon comparison, if the measured load is greater than the reference load, it is determined as an overload and the operation frequency is increased by as much as a certain value higher than an oscillation frequency, for performing an overload operation.

[0004] US Patent Application US 2002/0064463 A1 discloses an apparatus for controlling an operation of a linear compressor. A sensorless circuit unit is used for detecting a current and a voltage applied to a linear compressor and outputting a work operation value corresponding to them. A stroke controller is used for receiving the work operation value and outputting a switching control signal corresponding to a variation amount of the work operation value; and an electric circuit unit for receiving the switching control signal from the stroke controller and outputting a certain voltage to the linear compressor.

[0005] US Patent Application US 2007/0152512 A1 discloses a free piston gas compressor which has a cylinder, a piston reciprocable within the cylinder in alternating compression and expansion strokes. A reciprocating linear electric motor is drivably coupled to the piston. A controller is programmed to control or adjust power input to the linear motor.

[0006] US Patent Application US 2003/0021693 A1 discloses a system and method for controlling a compressor. The system and method control the stroke of the piston, allowing the piston to advance as far as the end of its mechanical stroke in extreme conditions of load, without allowing the piston to collide with the valve system.

[0007] US Patent Application US 2007/0276544 A1 discloses a system and a method of controlling a fluid pump with means to calibrate the respective functioning at the time of the first use or in cases of problems caused by electric or mechanical failures. The fluid pump is provided with a piston-position sensing assembly, the electronic controller monitoring the piston displacement within the respective cylinder by detecting an impact signal.

[0008] US Patent US 3,742,256 discloses a fuel pump driver circuit for an internal combustion engine. A voltage supply energizes the fuel pump through an output or switch transistor. The output transistor is turned off to stop the pump by a control transistor, which is controlled by a differential amplifier or switch.

[0009] US Patent Application US 2010/0037644 A1 discloses a condensate pump for an HVAC system. The pump includes besides others a solenoid pump electronic control module for limiting the amount of energy delivered to the solenoid pump during one half cycle from an AC current source.

[0010] Known electronic control module solenoid pumps use internally located timer chips to generate the pulse drive to the output stage of the pump. Pump pulse on and off times are automatically generated by the timer chip. Unless there is a failure of the timer chip, the pump pulse will always be within the specified safe area range of the output stage. However, current electronic control module pumps do not allow for external sources to control the pump pulses.

[0011] Thus, there is a long felt need for a solenoid pump with a control unit that allows a signal source that is external to the control unit and solenoid pump to energize/de-energize the solenoid coil, while maintaining safe solenoid pump operating times.

SUMMARY

[0012] The invention is set out in the appended claims.

[0013] These and other objects, features, and advantages of the present disclosure will become readily apparent upon a review of the following detailed description of the disclosure, in view of the drawings and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Various embodiments are disclosed, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, in which:

Figure 1 is a top elevational view of an electronic control module solenoid pump; and,

Figure 2 is a side elevational view of the electronic control module solenoid pump shown in Figure 1;

Figure 3 is an exploded view of the electronic control module solenoid pump shown in Figure 1;

Figure 4A is a cross-sectional view of the electronic control module solenoid pump taken generally along line 4-4 in Figure 1, in a rest position;

Figure 4B is a cross-sectional view of the electronic control module solenoid pump taken generally along line 4-4 in Figure 1, in an energized position;

Figure 4C is a cross-sectional view of the electronic control module solenoid pump taken generally along line 4-4 in Figure 1, in a de-energized position; and,

Figure 5 depicts an exemplary power circuit for a control scheme for energizing/de-energizing solenoid coil according to external signals.

DETAILED DESCRIPTION

[0015] At the outset, it should be appreciated that like drawing numbers on different drawing views identify identical, or functionally similar, structural elements. It is to be understood that the claims are not limited to the disclosed aspects.

[0016] Furthermore, it is understood that this disclosure is not limited to the particular methodology, materials and modifications described and as such may, of course, vary. It is also understood that the terminology used herein is for the purpose of describing particular aspects only, and is not intended to limit the scope of the claims.

[0017] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure pertains. It should be understood that any methods, devices or materials similar or equivalent to those described herein can be used in the practice or testing of the example embodiments. The assembly of the present disclosure could be driven by hydraulics, electronics, and/or pneumatics.

[0018] It should be appreciated that the term "substantially" is synonymous with terms such as "nearly," "very nearly," "about," "approximately," "around," "bordering on," "close to," "essentially," "in the neighborhood of," "in the vicinity of," etc., and such terms may be used interchangeably as appearing in the specification and claims. It should be appreciated that the term "proximate" is synonymous with terms such as "nearby," "close," "adjacent," "neighboring," "immediate," "adjoining," etc., and such terms may be used interchangeably as appearing in the specification and claims. The term "approximately" is intended to mean values within ten percent of the specified value.

[0019] Adverting now to the figures, Figure 1 is a top elevational view of electronic control module solenoid pump **100**. Figure 2 is a side elevational view of electronic control module solenoid pump **100** shown in Figure 1. Electronic control module solenoid pump **100** comprises housing **102** having inlet port **104** and outlet port **106**. In some embodiments, housing **102** comprises main housing **102A**, inlet housing **102B**, and outlet housing **102C**. Inlet housing **102B** and outlet housing **102C** are connected to main housing **102A** by any means known in the art, for example, threads and adhesives. Electronic control module solenoid pump **100** further comprises power input line **222A**, signal input line **222B**, and ground line **222C**. In some embodiments, power input line **222A**, signal input line **222B**, and ground line **222C** are connected to electronic control module solenoid pump **100** through main housing **102A**. Electronic control module solenoid pump **100** may be, for example, a high pressure solenoid pump or any other suitable solenoid pump. In some embodiments, electronic control module solenoid pump **100** is controlled using pulse width modulation.

[0020] Figure 3 is an exploded view of electronic control module pump **100**. As shown in Figure 3, electronic control module solenoid pump **100** further comprises, from left to right, seal 130A, bumper spring **132**, sleeve **128**, plunger **110**, suction valve assembly **138**, spring **114**, one-way check valve **150**, and seal **130B**.

[0021] Figures 4A-4C are respective cross-sectional views of electronic control module solenoid pump **100** taken generally along line **4-4** in Figure 1, depicting various stages of a pumping cycle. The following should be viewed in light of Figures 1 through 4C. Electronic control module solenoid pump **100** comprises through-bore **108**, plunger **110**, solenoid coil **116**, and control unit **118**. In some embodiments, electronic control module solenoid pump **100** may comprise one or more solenoid coils. Through-bore **108** connects inlet port **104** and outlet port **106**. Plunger **110** is disposed within through-bore **108** and includes through-bore **112**. Spring **114** is arranged in electronic control module solenoid pump **100** to urge plunger **110** toward outlet port **106**. Solenoid coil **116** is arranged in electronic control module solenoid pump **100**, specifically within main housing **102A,** to displace plunger **110** toward inlet port **104** in response to power being applied to solenoid coil **116**. Control unit **118** is arranged within electronic control module solenoid pump **100**, specifically within main housing **102A,** for controlling the operation of solenoid coil **116**.

[0022] Spring **114** is a variable rate spring. By "variable rate spring" it is meant that the force of spring **114** increases as spring **114** is compressed in direction **A1** toward inlet port **104**, for example, by plunger **110**. Stated otherwise, referring to Hooke's Law: $F = -kx$, the constant k for the spring increases as the spring is compressed. Thus, the further the spring is compressed, the more force is needed to continue compressing the spring. For example, when plunger **110** begins displacing in direction **A1** from the position shown in Figure 4A, a certain amount of force is required to compress spring **114**. As plunger **110** continues to displace to the position shown in Figure 4B, an increasingly greater amount of force is required to continue compressing spring **114**. The rate for spring **114** may vary according to pump type and the pressure output of the pump, and the spring characteristics may be varied accordingly, for example k for the spring.

[0023] Spring **114** has a frusto-conical shape, for example, diameter **D1** at end **120** of spring **114** is less than diameter **D2** at end **122** of spring **114**, opposite end **120** (as shown in Figure 3). Thus, when spring **114** is compressed as shown in Figure 4B, compressed coils **124** of spring **114** are aligned in direction **R** orthogonal to longitudinal axis **126**, which passes through inlet port **104** and outlet port **106**. In some embodiments, spring **114** is cylindrical in shape.

[0024] Sleeve **128** is arranged within bore **108** and displaceable parallel to longitudinal axis **126**. Plunger **110** is arranged within sleeve **128** and is displaceable therein parallel to longitudinal axis. Seals **130A** and **130B** are arranged to provide a seal between housing **102** and sleeve **128**, while enabling movement of sleeve **128** within bore **108**. Seals **130A** and **130B** may be any suitable seal, such as O-rings. Sleeve **128** has length **L1**, which is less than length **L2** of bore **108** and allows sleeve **128** to "float" within bore **108**. Advantageously, this floating design increases the ease of fabrication of electronic control module solenoid pump **100**, since fabrication steps that would be needed to fix sleeve **128** within electronic control module solenoid pump **100** are eliminated. Further, this floating design enables greater flexibility since sleeves of different lengths can be easily installed. Also, since length **L1** is less than length **L2**, tolerances for length **L1** can be relaxed, reducing manufacturing cost and complexity. In some embodiments, sleeve **128** is made from a non-magnetic material.

[0025] In some embodiments, plunger **110** is arranged to pass fluid through through-bore **112** and longitudinally traverses electronic control module solenoid pump **100** between inlet port **104** and outlet port **106.** In some embodiments, bumper spring **132** is disposed in end **134** of plunger **110**. Bumper spring **132** contacts shoulder **136** in housing **102** to cushion the impact of plunger **110** as plunger **110** moves from the position of Figure 4B to the position of Figure 4A. Sleeve **128** serves as the primary location wherein mechanical pumping operations are performed. Suction valve assembly **138** is disposed at end **140** of plunger **110**. In some embodiments, suction valve assembly **138** comprises cap **142**, seat **144**, and stem **146**, which passes through retainer element **148**. The operation of the suction valve assembly is described in greater detail below.

[0026] Electronic control module solenoid pump **100** further comprises one-way check valve **150**. One-way check valve **150** enables fluid flow through inlet port **104** toward outlet port **106** in direction **A2**, and blocks fluid flow in direction **A1**, opposite direction **A2**. In some embodiments, one-way check valve **150** comprises valve housing **154** and sealing element **152**, which is arranged within valve housing **154**. Sealing element **152** seals against the housing, for example, inlet housing **102B** blocks fluid from flowing out of electronic control module solenoid pump **100** through inlet port **104**. For example, one-way check valve **150** is arranged to draw fuel from a fuel source such as a fuel tank.

[0027] Figure 4A is a cross-sectional view of electronic control module solenoid pump **100** taken generally along line **4-4** in Figure 1, in a rest position. Figure 4A shows plunger **110**, suction valve assembly **138**, one-way check valve **150**, and spring **114** in respective rest positions. While solenoid coil **116** is not energized, spring **114** biases, or urges, plunger **110** in direction **A2** such that bumper spring **132** is in contact with shoulder **136**. If backpressure exists, i.e., pressure caused by fluid entering from outlet port **106**, cap **142** forms a seal with seat **144** to prevent fluid from flowing from bore **112** past suction valve assembly **138** in direction **A1**. Sealing element **152** prevents fluid from flowing past one-way check valve **150** in direction **A1** and out through inlet port **104**.

[0028] Figure 4B is a cross-sectional view of electronic control module solenoid pump **100** taken generally along line **4-4** in Figure 1, in an energized position. In Figure 4B, solenoid coil **116** is energized thereby forming a magnetic field. The magnetic field created by the energized solenoid coil **116** imparts a directional force upon plunger **110** in direction **A1** toward inlet port **104**. This directional force causes plunger **110** to displace in direction **A1** and spring **114** to compress. As a result of the movement in direction **A1** and the configuration of suction valve assembly **138**, a negative pressure, or suction, is formed in chamber **158** of bore **108** and bore **112**, displacing cap **142** from seat **144**. Fluid present in chamber **156** just prior to energizing coil **116** is sucked around suction valve assembly **138**, as shown by flow lines **F1**, and into bore **112** and chamber **158**. During this stage, fluid is prevented from moving between chamber **156** and inlet port **102** by one-way check valve **150**.

[0029] Figure 4C is a cross-sectional view of electronic control module solenoid pump **100** taken generally along line **4-4** in Figure 1, in a de-energized position. As solenoid coil **116** is de-energized, the magnetic field collapses. As a result, plunger **110** is no longer acted upon by a magnetic force and is urged in direction **A2** toward the rest location of Figure 4A by the bias of spring **114**. Two simultaneous events occur during the movement of plunger **110** in direction **A2**. First, fluid contained in bore **112** and chamber **158** is forced out of outlet port **104**, as shown by fluid flow lines **F2**. The fluid in bore **112** and chamber **158** is prevented from entering chamber **156** by the seal created between cap **142** and seat **144**. Second, and simultaneously, fluid is replenished in chamber **156** as follows. As plunger **110** moves in direction **A2**, a negative pressure, or suction, is created in chamber **156**. The negative pressure causes one-way check valve **150** to open, allowing fluid to be drawn from inlet port **102** into chamber **156**, as shown by fluid flow lines **F3**. The operation described above regarding Figures 4A-4C is cyclically repeated during the use of electronic control module solenoid pump **100**.

[0030] As noted above, some amount of back pressure, that is, pressure exerted through outlet port **106** into bore **108** in direction **A1**, is typically present during operation of electronic control module solenoid pump **100**. The back pressure biases plunger **110** in direction **A1**, against the biasing of spring **114**. When the force of the back pressure is greater than the force exerted by spring **114**, for example, spring **114** no longer can urge plunger **110** in direction **A2** from the position in Figure 4B, the reciprocating action of plunger **110** is terminated, and fluid no longer can be transferred as described above. Known solenoid pumps using nominal 12 VDC input power cannot operate (pump fluid) above about 10 psi of back pressure.

[0031] Advantageously, electronic control module solenoid pump **100** is able to operate (pump fluid) up to about 15 psi of back pressure. The ability of electronic control module solenoid pump **100** to operate at greater back pressures is at least partly due to the variable rate of spring **114**. Due to the characteristics associated with operation of solenoid coil **116**, it is desirable to minimize the amount of resistance plunger **110** must overcome at the onset of a cycle. As noted above, the variable rate results in spring **114** advantageously generating relatively less biasing force resisting movement of plunger **110** in direction **A1** at the onset of a pump cycle, for example, starting in the position of Figure 4A. Also as noted above, the biasing force of spring **114** increases as spring **114** is compressed, such that in the position shown in Figure 4B, the biasing force is maximized. This maximized force initiates the movement of plunger **110** in direction **A2** after solenoid coil **116** is de-energized. Advantageously, the biasing force generated by spring **114** when solenoid coil **116** is de-energized determines the amount of back pressure under which electronic control module solenoid pump **100** can operate. That is, the greatest amount of biasing force from spring **114** is needed to initiate displacement of plunger **110** against the back pressure when solenoid coil **116** is de-energized. Thus, spring **114** provides the least resistance when less resistance is advantageous, that is, when solenoid coil **116** is first energized and the displacement of plunger **110** in direction **A1** begins. Spring **114** provides the most resistance when more resistance is advantageous, that is, when solenoid coil **116** is de-energized and spring **114** must operate against the back pressure.

[0032] Electronic control module solenoid pump **100** can be used in common rail systems. As noted above, in a common rail system a relatively low pressure pump is used to pump fuel from a fuel source to a high pressure pump. For a common rail system, the back pressure on the outlet port of the low pressure pump is greater than the 10 psi maximum backpressure under which known solenoid pumps can operate. Advantageously, the approximately 15 psi maximum backpressure under which solenoid pump **100** can operate is sufficient to enable operation of solenoid pump **100** in a common rail system. It should be appreciated, however, that electronic control module solenoid pump **100** can be used in any low pressure pumping system and that the present disclosure should not be limited to only common rail systems.

[0033] Electronic control module solenoid pump **100** is referenced in the discussion that follows; however, it should be understood that the control scheme described below is applicable to any solenoid pump using a solenoid coil to displace an element to transfer fluid from an inlet port for the pump to an outlet port for the pump. Control unit **118** is arranged to control the operation of the solenoid coil. Control unit **118** is arranged to accept input voltage **V**, for example, from an outside source, such as a battery of a vehicle in which the pump is installed. It should be understood that any source of direct current electricity known in the art can be used to provide input voltage **V**. A continuous input voltage **V** is provided to control unit **118**, specifically to externally controlled circuit **220**, via power input line **222A**. Electronic control module solenoid pump **100** is grounded via ground line **222C**. Ground line **222C** is the direct physical connection of externally controlled circuit **220** to earth. Control unit **118** is also arranged to accept a signal **S**. In some embodiments, signal **S** is provided to control unit **118**, specifically to externally controlled circuit **220**, via signal input line **222B**. It should be appreciated that signal **S** may be provided to control unit **118** via wireless communication, in which case externally controlled circuit **220** would have a wireless communication receiver.

[0034] Figure 5 depicts externally controlled circuit **220** for a control scheme for energizing/de-energizing solenoid coil **116** according to external signals. The following should be viewed in light of Figures 4A through 5. Electronic control module solenoid pump **100** is used as an example in the discussion that follows. However, it should be understood that the control scheme described below is applicable to any pump using a solenoid coil to displace an element to transfer fluid from an inlet port for the pump to an outlet port for the pump and is not limited to electronic control module solenoid pump **100**. In some embodiments, control unit **118** includes externally controlled circuit **220** shown in Figure 5. Although externally controlled circuit **220** is described with respect to control unit **118**, it should be understood that externally controlled circuit **220** is applicable to any pump using a solenoid coil to displace an element to transfer fluid from an inlet port for the pump to an outlet port for the pump and is not limited to control unit **118**.

[0035] As shown, externally controlled circuit **220** generally comprises power input line **222A,** signal input line **222B**, and ground line **222C**. Input voltage V is continuously provided to externally controlled circuit **220**, specifically to solenoid coil **116**. Externally controlled circuit 220 further comprises microcontroller **U1**. Microcontroller **U1** may be, for example, a PIC12F752-E/MF microcontroller manufactured by Microchip Technology. Microcontroller **U1** is programmable and operates to energize and de-energize solenoid coil **116** in response to signal **S**.

[0036] In some embodiments, externally controlled circuit **220** comprises the following: Power header **J1** is connected to power input line **222A**. Ground header **J2**

is connected to ground line **222C**. Diode **D1** provides reverse polarity protection to ensure that nothing will happen if a negative voltage is applied to the power header **J1**. Diode **D1** may be, for example, a SSC54-E3/57T diode manufactured by Vishay Semiconductor Diodes Division. **D2** is a transient voltage suppressor (TVS). In some embodiments, diode **D2** may be a transient voltage suppression diode that is simply a Zener diode designed to protect electronics device against overvoltages. In some embodiments, diode **D2** comprises metal-oxide varistors (MOV) that protect electronic circuits and electrical equipment. Diode **D2** may be, for example, a SMCJ24A diode manufactured by Littelfuse. Power regulator **U2** regulates power from power header **J1** by reducing the input voltage V down to a voltage suitable for use by microcontroller **U1** and the transistors throughout externally controlled circuit **220**. Power regulator **U2** may, for example, be a LM2936MM-5.0 power regulator manufactured by Texas Instruments. In some embodiments, a 12 Volt battery provides continuous input voltage **V** to power header **J1** and power regulator **U2** reduces this to 4.5 Volts to be used by the various components of externally controlled circuit **220**. Resistor **R6** is arranged between power regulator **U2** and power header **J1**. Specifically, resistor **R6** is arranged between power regulator **U2** and voltage protection diodes **D1** and **D2**. Resistor **R6** may be, for example, a 100 Ω resistor. Capacitor **C1** eliminates high frequency noise associated with the regulated power of power regulator **U2** (i.e., the 4.5 Volt output). Capacitor **C1** may be, for example, a 1 μF 25 V capacitor. Capacitor **C2** eliminates high frequency noise associated with power header **J1** (i.e., the 12 Volt input). Capacitor **C2** may be, for example, a 1 μF 50 V capacitor. Coil header **J3** represents one end of solenoid coil **116** and coil header **J4** represents the other end of solenoid coil **116**. Diode **D5** is a TVS diode arranged to suppress voltage spikes that occur when the inductive coil, or solenoid coil **116**, is disconnected. Diode **D5** may be, for example, a SMLJ51CA diode manufactured by Bourns. Transistor **Q1** is the main transistor of externally controlled circuit **220**. Transistor **Q1** switches solenoid coil **116** on and off. Transistor **Q1** may be, for example, an IRFS4615TRLPBF transistor manufactured by Infineon. Resistor **R5** is a current limiting resistor arranged between transistor **Q1** and microcontroller **U1**. Resistor **R5** may be, for example, a 1 Ω resistor. Microcontroller **U1** is supplied power (i.e., 4.5 Volts) from power regulator **U2**. Microcontroller **U1** may comprise eight or nine pins. In some embodiments, pin 1 is voltage supply, pins 2 and 3 are input/output pins that can be set to either input for data collection or output for control scheme, pin 4 allows programming memory to be cleared (i.e., if pin 4 is grounded or low it will clear memory, if high it will operate as intended), pin 5 is used as an output, pin 6 is used as a clock input for programming (could also output an internal clock signal), pin 7 is used as an input pin for data coming in from programming header **J6** (info is actually sent when programming the chip), pin 8 is the grounding pin, pin 9 is used for mechanical and thermo coupling. It should be appreciated that any suitable microcontroller may be used with any suitable number of pins. For example, microcontroller **U1** may be a dual flat no lead (DFN) microcontroller, small outline integrated circuit 8 (SOIC 8) microcontroller, or a quad flat no lead (QFN) microcontroller. Capacitor **C3** eliminates high frequency noise associated with the regulated power of power regulator **U2** (i.e., the 4.5 Volt output). Capacitor **C3** may be, for example, a 0.1 μF capacitor. Capacitor **C4** eliminates high frequency noise. Diode **D4** is a diode clamp or clamping circuit. Capacitor **C4** may be, for example, a 3,900 pF 50 V capacitor. Diode **D4** supplies extra voltage if a signal comes in below 0 Volts, and leads off voltage if a signal comes in above 4.5 Volts. Diode **D4** may be, for example, a TBAT54S diode manufactured by Toshiba Semiconductor and Storage. Resistor **R4** is a pullup resistor to ensure that pin 4 stays high. In other words, resistor **R4** ensures that pin 4 remains at the high voltage level (4.5 Volts) instead of the low voltage state or ground level (0 Volts). Resistor **R4** may be, for example, a 10 Ω resistor. Programming header **J6** is the programming header used to actually transmit code into microcontroller **U1**. Programing header **J6** may be used to program solenoid coil **116** on/off time intervals in case of external signal source failure, as is described in Patent No. 9,500,190 (Moreira-Espinoza). Resistor **R3** is a pulldown resistor to ensure that pin 2 stays low. In other words, resistor **R3** ensures that pin 2 remains at the low voltage level or ground level (0 Volts) when no signal is occurring instead of the high voltage level (4.5 Volts). Resistor **R3** may be, for example, a 3 Ω resistor. Resistor **R2** is a current limiting resistor arranged between microcontroller **U1** and transistor **Q2**. Resistor **R2** may be, for example, a 12.7 Ω resistor. Transistor **Q2** is arranged as a switch when voltage comes in on signal header **J5**. Transistor **Q2** receives a signal **S** from signal header **J5**, and then provides a signal to microcontroller **U1** to energize the solenoid coil **116**. Transistor **Q2** receives a signal **S** from signal header **J5**, and then provides a signal to microcontroller **U1** to de-energize the solenoid coil **116**. Transistor **Q2** may be, for example, a BSS138 transistor manufactured by ON Semiconductor. Resistor **R7** is a current limiting resistor arranged between signal header **J5** and transistor **Q2**. Resistor **R7** may be, for example, a 47 Ω resistor. Diode **D3** provides reverse polarity protection to ensure that nothing will happen if a negative voltage is applied to the signal header **J5**. Diode **D3** may be, for example, a 1N5819 diode manufactured by ON Semiconductor. Resistor **R1** and transistor **Q3** are used for diagnostic purposes. Namely, resistor **R1** and transistor **Q3** are used to determine whether electronic control module solenoid pump **100** is connected/disconnected. Resistor **R1** may be, for example, a 1 Ω resistor. Transistor **Q3** may be, for example, a BSS138 transistor manufactured by ON Semiconductor.

[0037] Microcontroller **U1** operates two fold: first, microcontroller **U1** generally acts as a switch to energize/de-energize solenoid coil **116**. Generally, microcontroller **U1** receives a signal from transistor **Q2** and relays a signal to transistor **Q1** to energize/de-energize solenoid coil **116**. Second, microcontroller **U1** acts as a pump regulator. If the signal from transistor **Q2** goes high for too long (i.e., a continuous high voltage is provided for a prolonged period of time), microcontroller **U1** will revert to standard timing as that described in Moreira-Espinoza. As long as the signal line is connected to a voltage input, electronic control module solenoid pump **100** can be operated like any other pump. This design and the programming of microcontroller **U1** prevents the user from holding solenoid coil **116** on and creating a high current situation. This programming is software controlled by programming header **J6**.

[0038] In some embodiments, an external signal source sends a signal **S1** to externally controlled circuit **220** via signal input line **222B** (signal header **J5**). Signal **S1** causes transistor **Q2** to switch on, thereby completing a circuit and energizing solenoid coil **116**. External signal source subsequently sends signal **S2** to externally controlled circuit **220** via signal input line **222B** (signal header **J5**). Signal **S2** causes transistor **Q2** to switch off, thereby breaking the circuit and de-energizing solenoid coil **116**. The functionality of externally controlled circuit **220**, namely energizing and de-energizing solenoid coil **116**, is dependent on the signals sent by the external signal source.

[0039] In some embodiments, an external signal source sends a signal **S1** to externally controlled circuit **220** via signal input line **222B** (signal header **J5**). Signal **S1** causes transistor **Q2** to switch on, thereby completing a circuit and energizing solenoid coil **116**. If external signal source subsequently malfunctions and fails to send signal **S2** to externally controlled circuit **220** via signal input line **222B** (signal header **J5**), solenoid coil **116** remains energized because transistor **Q2** has not received an external signal to switch off. However, externally controlled circuit **220** comprises a backup timing scheme programmed in microcontroller **U1**. Once solenoid coil **116** is energized for a period of time equal to or greater than a predetermined period of time, microcontroller **U1** sends a signal to transistor **Q1** to switch off. At this point transistor **Q1** switches off thereby breaking the circuit and de-energizing solenoid coil. Microcontroller **U1** is programmable such that any predetermined time period suitable on a pump by pump basis may be used. Therefore, because transistor **Q2** remains switched on due to the faulty external signal source (i.e., failed to provide a signal to switch transistor **Q2** off), microcontroller **U1** is preprogrammed to energize solenoid coil **116** for a particular time period $\mathbf{T_{on}}$, and de-energizes solenoid coil **116** for a particular time period $\mathbf{T_{off}}$ for example, while power is generated to operate solenoid coil **116**. This means that during each cycle of operation, plunger **110** is biased in direction **A1** by electromagnetic force for time period $\mathbf{T_{on}}$, and then biased in direction **A2** by spring **114** for time period $\mathbf{T_{off}}$. The reciprocal motion causes fluid to flow through inlet port **102** and one-way check valve **150** into chamber **156**, through suction valve assembly **138** into chamber **158**, and through outlet port **106**, thereby creating a continuous flow of fluid.

[0040] It will be appreciated that various aspects of the disclosure above and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art. The scope of the present invention is limited solely by the scope of the appended claims.

LIST OF REFERENCE NUMERALS

[0041]

100	Electronic control module pump
102	Housing
102A	Main housing
102B	Inlet housing
102C	Outlet housing
104	Inlet port
106	Outlet port
108	First through-bore
110	Plunger
112	Second through-bore
114	Spring
116	Solenoid coil
118	Control unit
120	End
122	End
124	Compressed coils
126	Longitudinal axis
128	Sleeve
130A	Seal
130B	Seal
132	Bumper spring
134	End
136	Shoulder
138	Suction valve assembly
140	End
142	Cap
144	Seat
146	Stem
148	Retainer element
150	One-way check valve
152	Sealing element
154	Valve housing
156	Chamber
158	Chamber
D1	Diameter
D2	Diameter
L1	Length
L2	Length
A1	Direction
A2	Direction

R	Direction
F1	Flow lines
F2	Flow lines
F3	Flow lines
220	Externally controlled circuit
222A	Power input line
222B	Signal input line
222C	Ground line
J1	Power header
J2	Ground header
J3	Coil header
J4	Coil header
J5	Signal header
J6	Programming header
D1	Diode
D2	Diode
D3	Diode
D4	Diode
D5	Diode
R1	Resistor
R2	Resistor
R3	Resistor
R4	Resistor
R5	Resistor
R6	Resistor
R7	Resistor
C1	Capacitor
C2	Capacitor
C3	Capacitor
C4	Capacitor
U1	Microcontroller
U2	Power regulator
Q1	Transistor
Q2	Transistor
Q3	Transistor
S	Signal
S1	Signal
S2	Signal
V	Input voltage

Claims

1. A solenoid pump (100) comprising:

a control unit (118);
an inlet (104) port;
an outlet port (106);
a first through-bore (108) connecting the inlet and outlet ports (104, 106);
a plunger (110) disposed within the first through-bore (108) and including a second through-bore (112);
a spring (114) arranged to urge the plunger (110) toward the outlet port (106);
a solenoid coil (116) disposed about a portion of the plunger (110) and arranged to displace the plunger (110) toward the inlet port (104) in response to direct current coil power applied to the solenoid coil (116);
the control unit (118) being **characterized by**:

a power header (J1) electrically connected to the solenoid coil (116);
a first transistor (Q1) electrically connected to the solenoid coil (116);
a microcontroller (U1) electrically connected to the first transistor (Q1); and,
a second transistor (Q2) electrically arranged between the microcontroller and the power header (J1) wherein the second transistor (Q2) being electrically connectable to a signal source that is external to the control unit and the solenoid pump;

wherein the microcontroller (U1) is adapted to receive a signal, the signal generated by the signal source, from the second transistor (Q2) and to relay the signal to the first transistor (Q1) to energize/de-energize the solenoid coil (116).

2. The solenoid pump (100) as recited in Claim 1, wherein the microcontroller (U1) is operatively arranged to control the solenoid coil (116), the second transistor (Q2) is operatively arranged to receive the external signal and communicate the signal to the microcontroller (U1) to control the solenoid coil (116), and the first transistor (Q1) is arranged between the microcontroller (U1) and the solenoid coil (116), the first transistor (Q1) is operatively arranged to energize and de-energize the solenoid coil (116) in response to the microcontroller (U1).

3. The solenoid pump (100) according to any preceding Claim, wherein the solenoid pump (100) is arranged to:

receive a first signal (S1) from the signal source to switch on the second transistor (Q2) and energize the solenoid coil (116); and,
receive a second signal (S2) from the signal source to switch off the second transistor (Q2) and de-energize the solenoid coil (116).

4. The solenoid pump (100) as recited in any preceding Claim, wherein the microcontroller (U1) is programmed to:

switch off the first transistor (Q1) after the solenoid coil (116) has been energized for a first predetermined time period (T_{ON}); and,
switch on the first transistor (Q1) after the solenoid coil (116) has been de-energized for a second predetermined time period (T_{OFF}).

5. The solenoid pump (100) as recited in Claim 4, wherein the microcontroller (U1) is arranged to be preprogramed with the first predetermined time period (T_{ON}) and the second predetermined time period (T_{OFF}).

6. The solenoid pump (100) as recited in any preceding Claim, further comprising a programming header (J6) connected to the microcontroller (U1).

7. The solenoid pump (100) as recited in any preceding Claim, further comprising a power regulator (U2).

8. The solenoid pump (100) as recited in any preceding Claim, further comprising a third transistor (Q3) electrically arranged between a signal header (J5) and the second transistor (Q2) to indicate whether the solenoid pump (100) is connected.

Patentansprüche

1. Magnetpumpe (100), umfassend:

eine Steuereinheit (118);
eine Einlassöffnung (104);
eine Auslassöffnung (106);
eine erste Durchgangsbohrung (108), welche die Einlass- und die Auslassöffnung (104, 106) verbindet;
einen Kolben (110), der innerhalb der ersten Durchgangsbohrung (108) angeordnet ist und eine zweite Durchgangsbohrung (112) umfasst;
eine Feder (114), die dazu ausgelegt ist, den Kolben (110) in Richtung der Ausgangsöffnung (106) zu drücken;
eine Magnetspule (116), die um einen Abschnitt des Kolbens (110) angeordnet ist und dazu ausgelegt ist, den Kolben (110) in Richtung der Einlassöffnung (104) zu verschieben als Reaktion auf eine an die Magnetspule (116) angelegte Gleichstrom-Spulenleistung;
wobei die Steuereinheit (118) **gekennzeichnet ist durch**:

einen Leistungsverteiler (J1), der mit der Magnetspule (116) elektrisch verbunden ist;
einen ersten Transistor (Q1), der mit der Magnetspule (116) elektrisch verbunden ist;
einen Mikrocontroller (U1), der mit dem ersten Transistor (Q1) elektrisch verbunden ist; und
einen zweiten Transistor (Q2), der elektrisch zwischen dem Mikrocontroller und dem Leistungsverteiler (J1) angeordnet ist, wobei der zweite Transistor (Q2) mit einer Signalquelle elektrisch verbindbar ist, die sich außerhalb der Steuereinheit und der Magnetpumpe befindet;

wobei der Mikrocontroller (U1) dazu ausgestaltet ist, ein Signal von dem zweiten Transistor (Q2) zu empfangen, wobei das Signal **durch** die Signalquelle erzeugt wird, und um das Signal an den ersten Transistor (Q1) zum Aktivieren/Deaktivieren der Magnetspule (116) weiterzuleiten.

2. Magnetpumpe (100) nach Anspruch 1, wobei der Mikrocontroller (U1) betriebsmäßig dazu ausgelegt ist, die Magnetspule (116) zu steuern, der zweite Transistor (Q2) betriebsmäßig dazu ausgelegt ist, das externe Signal zu empfangen und das Signal an den Mikrocontroller (U1) zum Steuern der Magnetspule (116) zu kommunizieren, und der erste Transistor (Q1) zwischen dem Mikrocontroller (U1) und der Magnetspule (116) angeordnet ist, wobei der erste Transistor (Q1) betriebsmäßig dazu ausgelegt ist, die Magnetspule (116) als Reaktion auf den Mikrocontroller (U1) zu aktivieren und zu deaktivieren.

3. Magnetpumpe (100) nach einem der vorhergehenden Ansprüche, wobei die Magnetpumpe (100) ausgelegt ist zum:

Empfangen eines ersten Signals (S1) von der Signalquelle, um den zweiten Transistor (Q2) einzuschalten und die Magnetspule (116) zu aktivieren; und
Empfangen eines zweiten Signals (S2) von der Signalquelle, um den zweiten Transistor (Q2) auszuschalten und die Magnetspule (116) zu deaktivieren.

4. Magnetpumpe (100) nach einem der vorhergehenden Ansprüche, wobei der Mikrocontroller (U1) programmiert ist zum:

Ausschalten des ersten Transistors (Q1), nachdem die Magnetspule (116) für einen ersten vorbestimmten Zeitraum (T_{EIN}) aktiviert war; und
Einschalten des ersten Transistors (Q1), nachdem die Magnetspule (116) für einen zweiten vorbestimmten Zeitraum (T_{AUS}) deaktiviert war.

5. Magnetpumpe (100) nach Anspruch 4, wobei der Mikrocontroller (U1) dazu ausgelegt ist, mit dem ersten vorbestimmten Zeitraum (T_{EIN}) und dem zweiten vorbestimmten Zeitraum (T_{AUS}) vorprogrammiert zu werden.

6. Magnetpumpe (100) nach einem der vorhergehenden Ansprüche, ferner umfassend einen Programmierkopf (J6), der mit dem Mikrocontroller (U1) verbunden ist.

7. Magnetpumpe (100) nach einem der vorhergehenden Ansprüche, ferner umfassend einen Leistungsregler (U2).

8. Magnetpumpe (100) nach einem der vorhergehenden Ansprüche, ferner umfassend einen dritten Transistor (Q3), der elektrisch zwischen einem Signalkopf (J5) und dem zweiten Transistor (Q2) angeordnet ist, um anzugeben, ob die Magnetpumpe (100) angeschlossen ist.

Revendications

1. Pompe à solénoïde (100) comprenant :

   une unité de commande (118) ;
   un orifice d'entrée (104) ;
   un orifice de sortie (106) ;
   un premier alésage traversant (108) reliant les orifices d'entrée et de sortie (104, 106) ;
   un plongeur (110) disposé au sein du premier alésage traversant (108) et comportant un second alésage traversant (112) ;
   un ressort (114) agencé pour pousser le plongeur (110) vers l'orifice de sortie (106) ;
   une bobine de solénoïde (116) disposée autour d'une portion du plongeur (110) et agencée pour déplacer le plongeur (110) vers l'orifice d'entrée (104) en réponse à une puissance de bobine à courant continu appliquée à la bobine de solénoïde (116) ;
   l'unité de commande (118) étant **caractérisée par** :

      une embase de puissance (J1) connectée électriquement à la bobine de solénoïde (116) ;
      un premier transistor (Q1) connecté électriquement à la bobine de solénoïde (116);
      un microcontrôleur (U1) connecté électriquement au premier transistor (Q1) ; et,
      un deuxième transistor (Q2) agencé électriquement entre le microcontrôleur et l'embase de puissance (J1) dans laquelle le deuxième transistor (Q2) peut être connecté électriquement à une source de signal qui est externe à l'unité de commande et à la pompe à solénoïde ;

   dans laquelle le microcontrôleur (U1) est adapté pour recevoir un signal, le signal étant généré par la source de signal, en provenance du deuxième transistor (Q2) et pour relayer le signal au premier transistor (Q1) afin de mettre sous tension/hors tension la bobine de solénoïde (116).

2. Pompe à solénoïde (100) selon la revendication 1, dans laquelle le microcontrôleur (U1) est agencé opérationnellement pour commander la bobine de solénoïde (116), le deuxième transistor (Q2) est agencé opérationnellement pour recevoir le signal externe et communiquer le signal au microcontrôleur (U1) afin de commander la bobine de solénoïde (116), et le premier transistor (Q1) est agencé entre le microcontrôleur (U1) et la bobine de solénoïde (116), le premier transistor (Q1) est agencé opérationnellement pour mettre sous tension et hors tension la bobine de solénoïde (116) en réponse au microcontrôleur (U1).

3. Pompe à solénoïde (100) selon l'une quelconque des revendications précédentes, dans laquelle la pompe à solénoïde (100) est agencée pour :

   recevoir un premier signal (S1) en provenance de la source de signal pour allumer le deuxième transistor (Q2) et mettre sous tension la bobine de solénoïde (116) ; et,
   recevoir un second signal (S2) en provenance de la source de signal pour éteindre le deuxième transistor (Q2) et mettre hors tension la bobine de solénoïde (116).

4. Pompe à solénoïde (100) selon l'une quelconque des revendications précédentes, dans laquelle le microcontrôleur (U1) est programmé pour :

   éteindre le premier transistor (Q1) après la mise sous tension de la bobine de solénoïde (116) pendant une première période prédéterminée (T_{ON}) ; et,
   allumer le premier transistor (Q1) après la mise hors tension de la bobine de solénoïde (116) pendant une seconde période prédéterminée (T_{OFF}).

5. Pompe à solénoïde (100) selon la revendication 4, dans laquelle le microcontrôleur (U1) est agencé pour être préprogrammé avec la première période prédéterminée (T_{ON}) et la seconde période prédéterminée (T_{OFF}).

6. Pompe à solénoïde (100) selon l'une quelconque des revendications précédentes, comprenant en outre une embase de programmation (J6) connectée au microcontrôleur (U1).

7. Pompe à solénoïde (100) selon l'une quelconque des revendications précédentes, comprenant en outre un régulateur de puissance (U2).

8. Pompe à solénoïde (100) selon l'une quelconque des revendications précédentes, comprenant en outre un troisième transistor (Q3) agencé électrique-

ment entre une embase de signal (J5) et le deuxième transistor (Q2) pour indiquer si la pompe à solénoïde (100) est connectée.

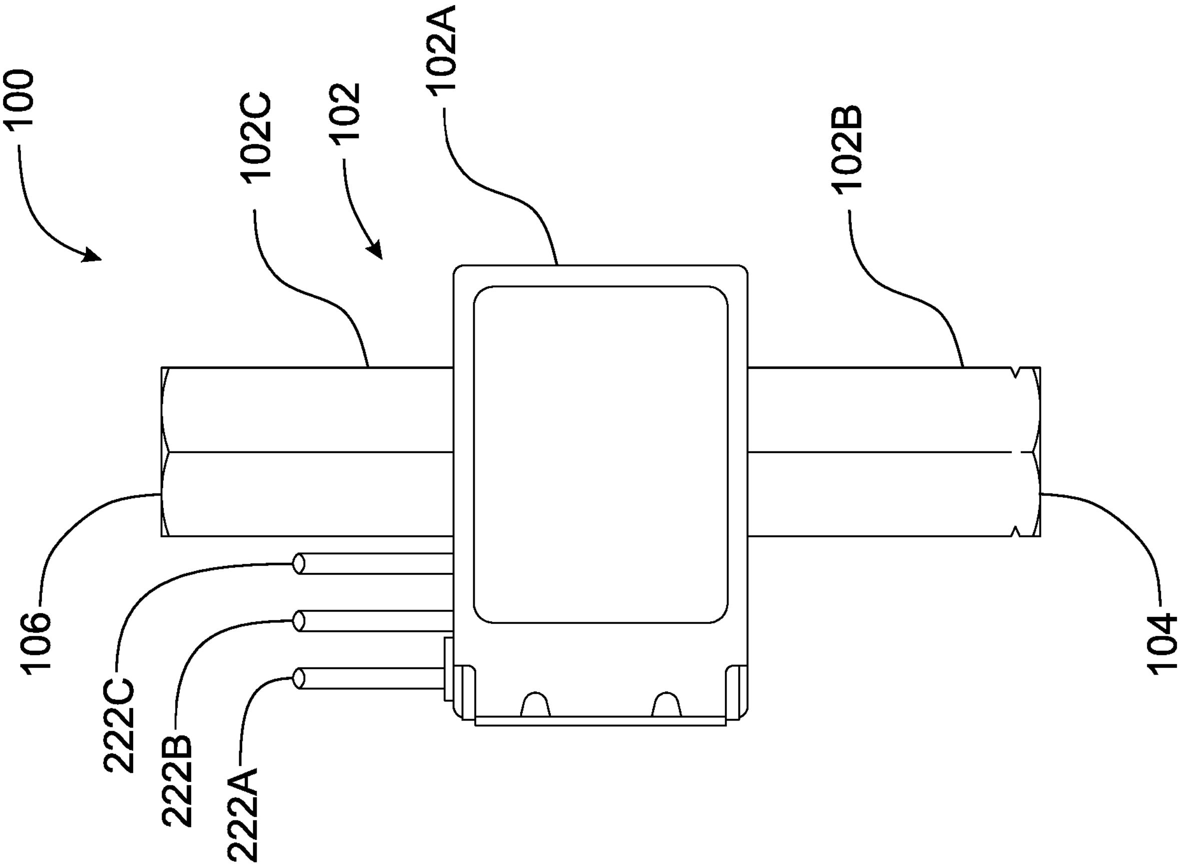

100
102C
102
102A
102B
106
222C
222B
222A
104

Fig. 2

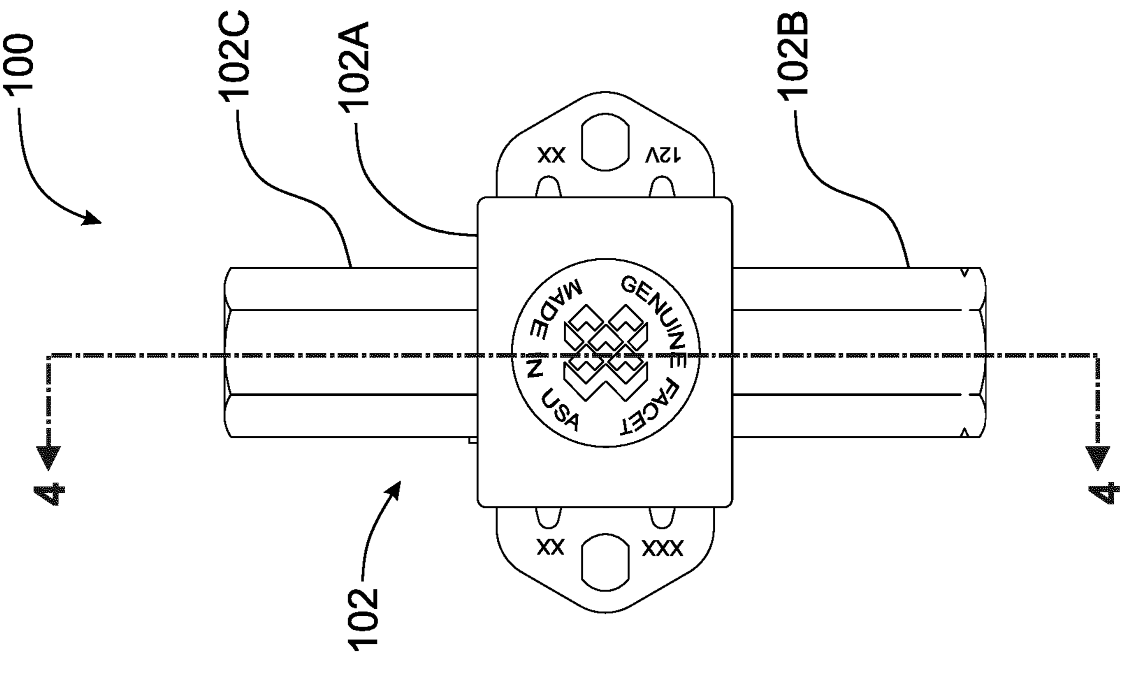

100
102C
102A
102B
4
4
102
XX
12V
XX
XXX
GENUINE FACET
MADE IN USA

Fig. 1

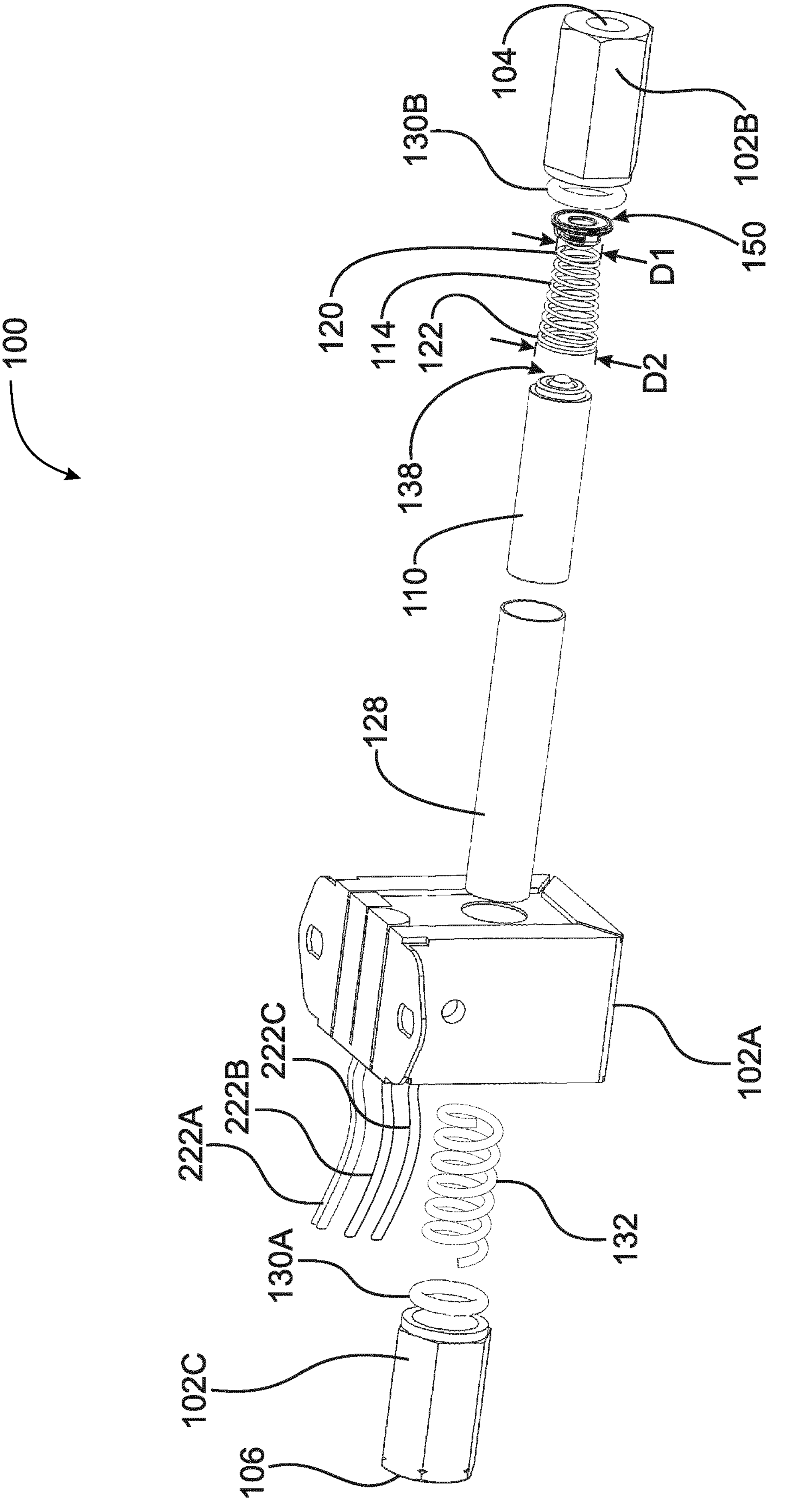

100
104
102B
130B
150
D1
120
114
122
D2
138
110
128
102A
222C
222B
222A
132
130A
102C
106

Fig. 3

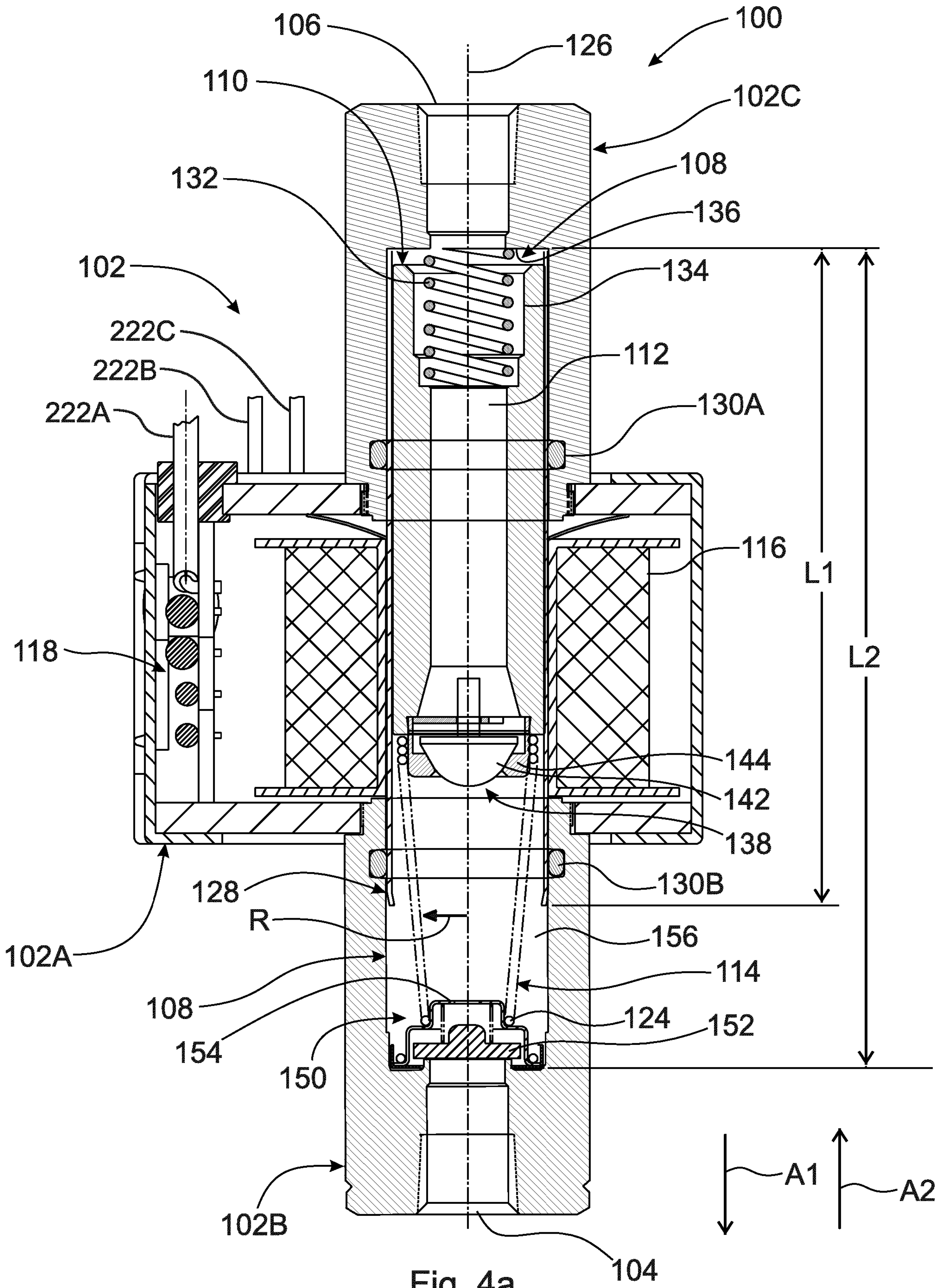

100
106
126
110
102C
132
108
136
102
134
222C
222B
112
222A
130A
116
L1
L2
118
144
142
138
130B
128
R
156
102A
108
114
124
152
154
150
A1
A2
102B
104

Fig. 4a

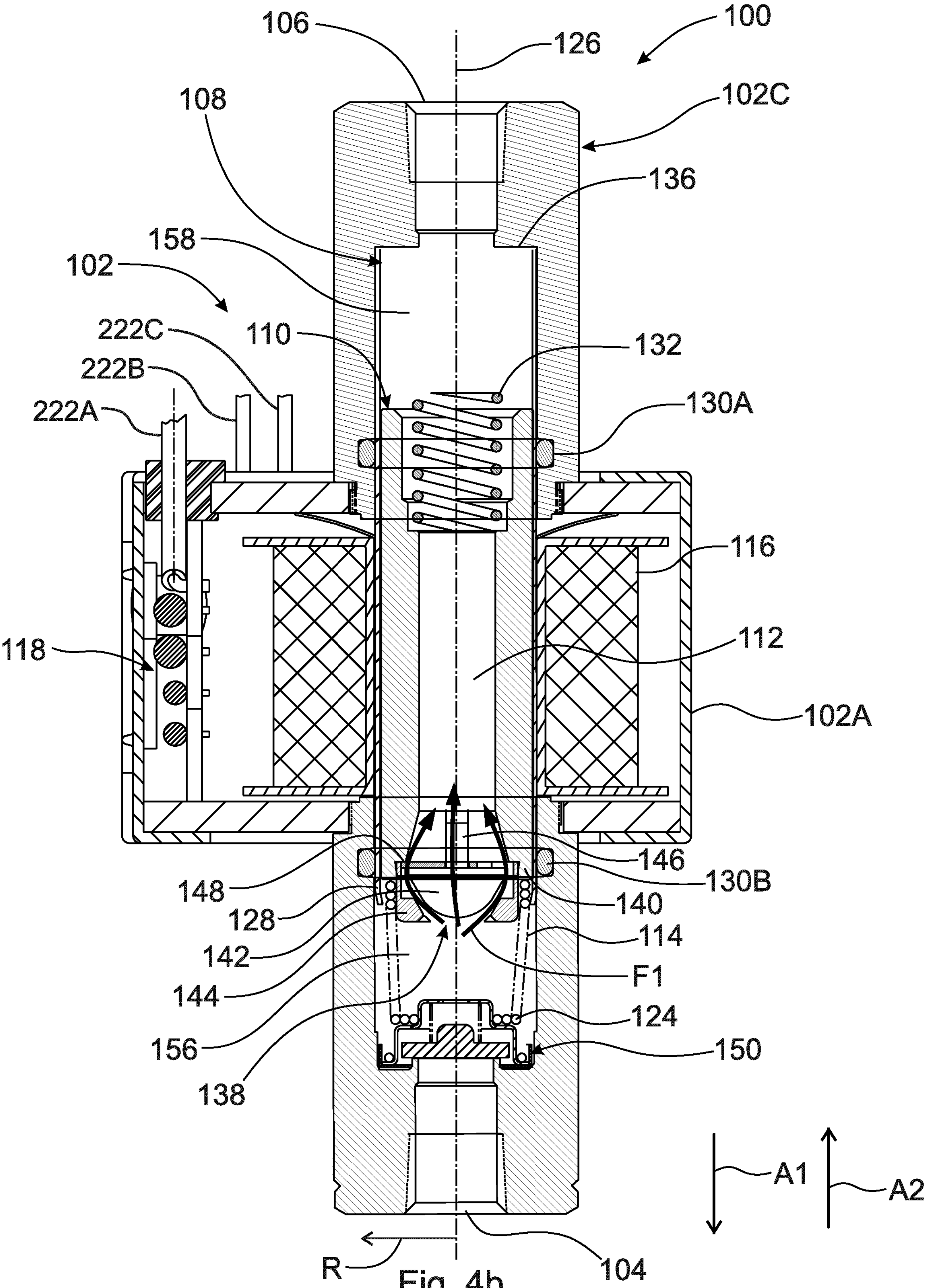
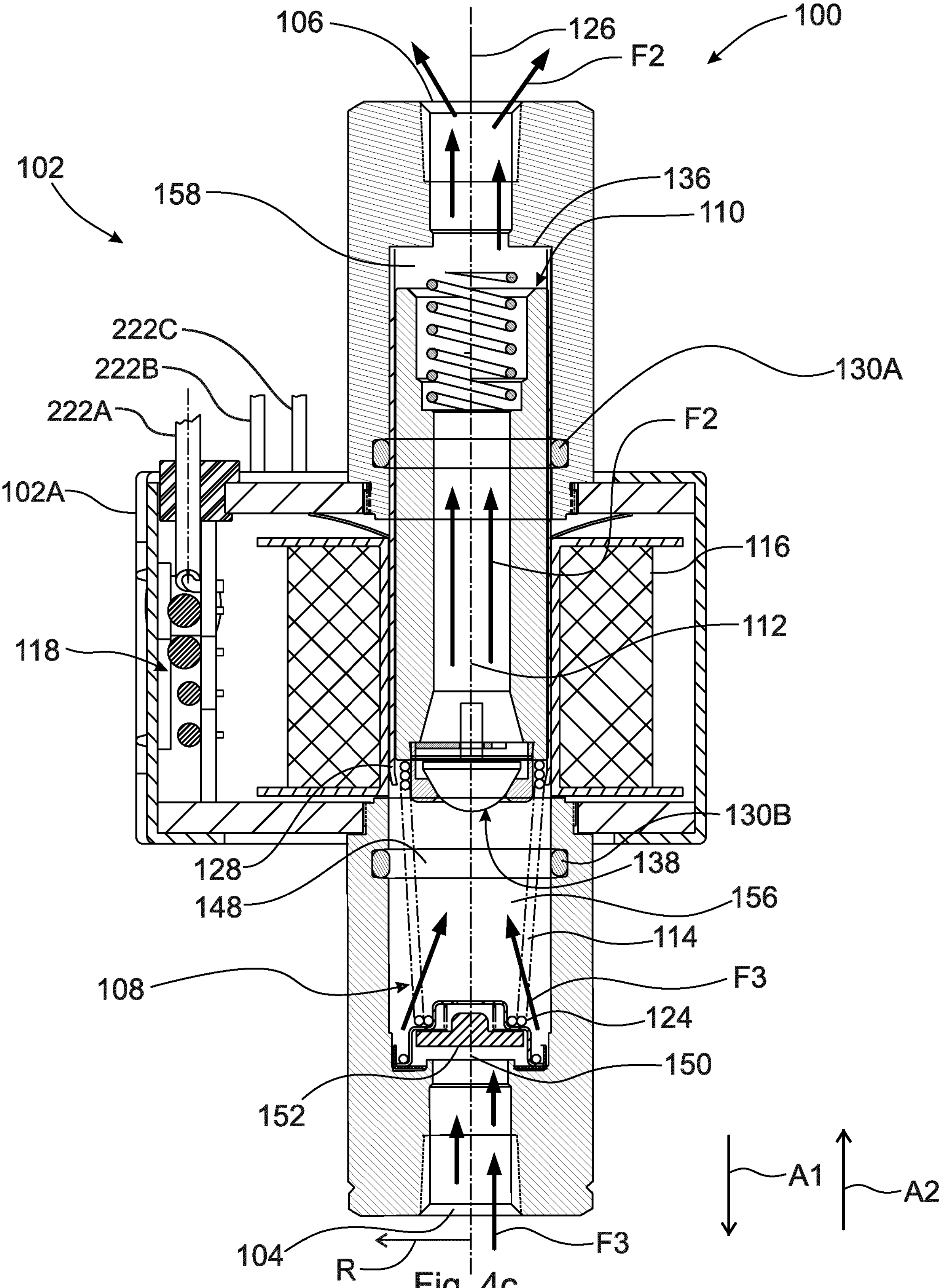

100
106
126
102C
108
136
158
102
110
132
222C
222B
222A
130A
116
118
112
102A
146
130B
148
140
128
114
142
F1
144
124
156
150
138
A1
A2
R
104

Fig. 4b


106
126
F2
100
102
158
136
110
222C
222B
222A
130A
F2
102A
116
112
118
130B
128
138
148
156
114
108
F3
124
150
152
A1
A2
104
F3
R
Fig. 4c

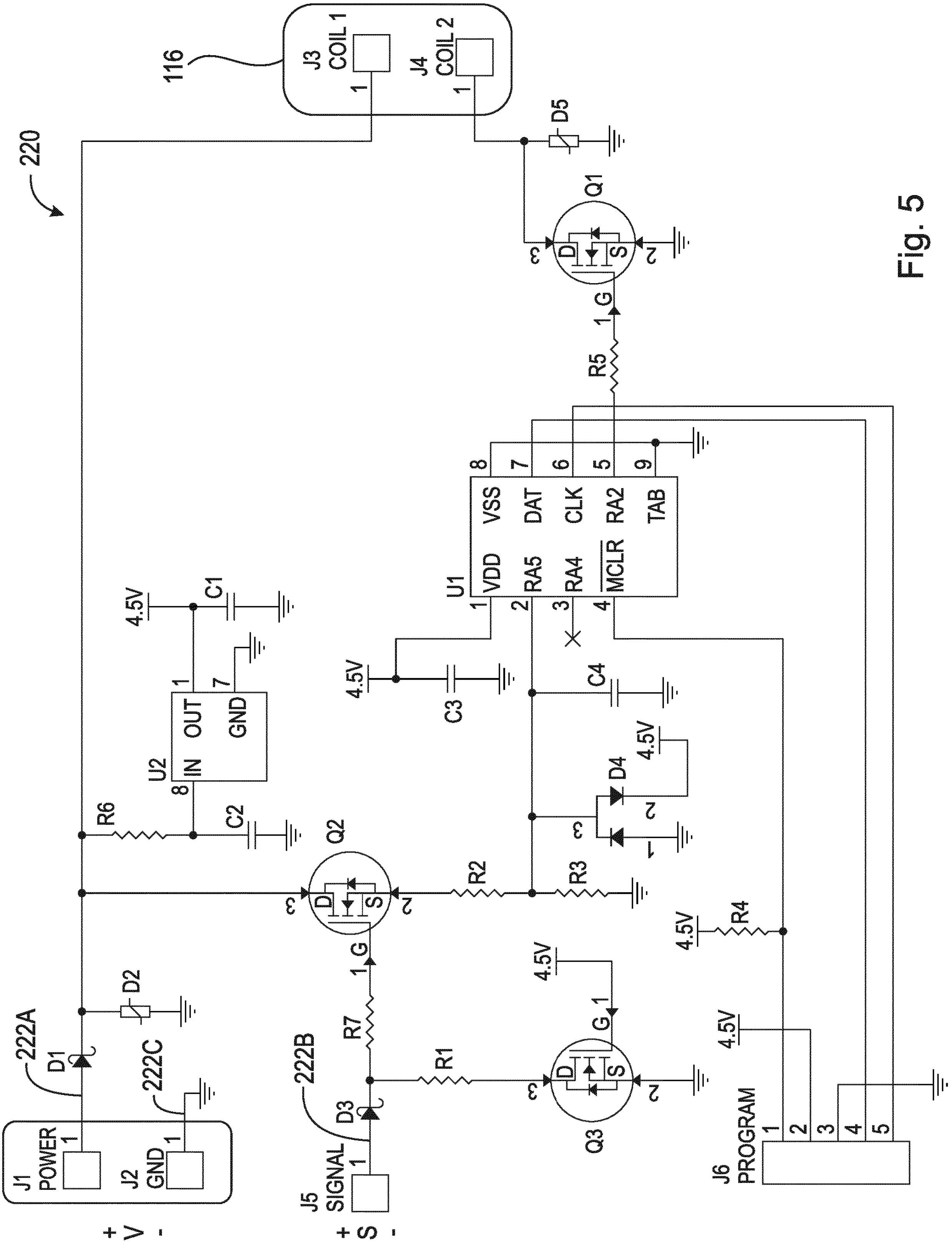

220
116
J3 COIL 1
J4 COIL 2
D5
Q1
R5
U1
VDD
RA5
RA4
MCLR
VSS
DAT
CLK
RA2
TAB
U2
IN
OUT
GND
4.5V
C1
C2
C3
C4
R6
R2
R3
R4
R1
R7
D4
Q2
Q3
D1
D2
D3
222A
222B
222C
J1 POWER
J2 GND
J5 SIGNAL
J6 PROGRAM
+ V -
+ S -

Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20030175125 A1 **[0003]**
- US 20020064463 A1 **[0004]**
- US 20070152512 A1 **[0005]**
- US 20030021693 A1 **[0006]**
- US 20070276544 A1 **[0007]**
- US 3742256 A **[0008]**
- US 20100037644 A1 **[0009]**
- WO 9500190 A, Moreira-Espinoza **[0036]**