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Yakos et al.

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(54) ELECTROMAGNETICALLY ACTIVATED PIPE VALVE

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F16K 31/08 (2006.01)
F16K 1/14 (2006.01)
F16K 31/04 (2006.01)

(52) **U.S. Cl.**

CPC ***F16K 31/043*** (2013.01); ***F16K 1/14*** (2013.01); ***F16K 31/082*** (2013.01)

(58) **Field of Classification Search**

CPC F16K 31/041; F16K 31/043; F16K 31/042; F16K 31/082; F16K 5/0647

See application file for complete search history.

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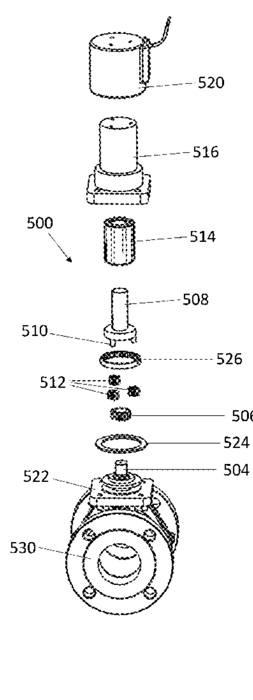
(74) *Attorney, Agent, or Firm* — NEO IP

(57) ABSTRACT

The present invention is directed to an electromagnetic actuation system for opening and closing pipe valves. The electromagnetic actuation systems utilizes one or more electromagnets surrounding one or more permanent magnets attached to a rotary shaft of the valve mechanism. A controller activates the one or more electromagnets such that the produced magnetic field rotates, thereby applying a force to the one or more permanent magnets and thus rotating the rotary shaft. The system does not require rotation of the one or more electromagnets relative to the one or more permanent magnets, advantageously reducing the number of moving parts within the valve system.

18 Claims, 17 Drawing Sheets



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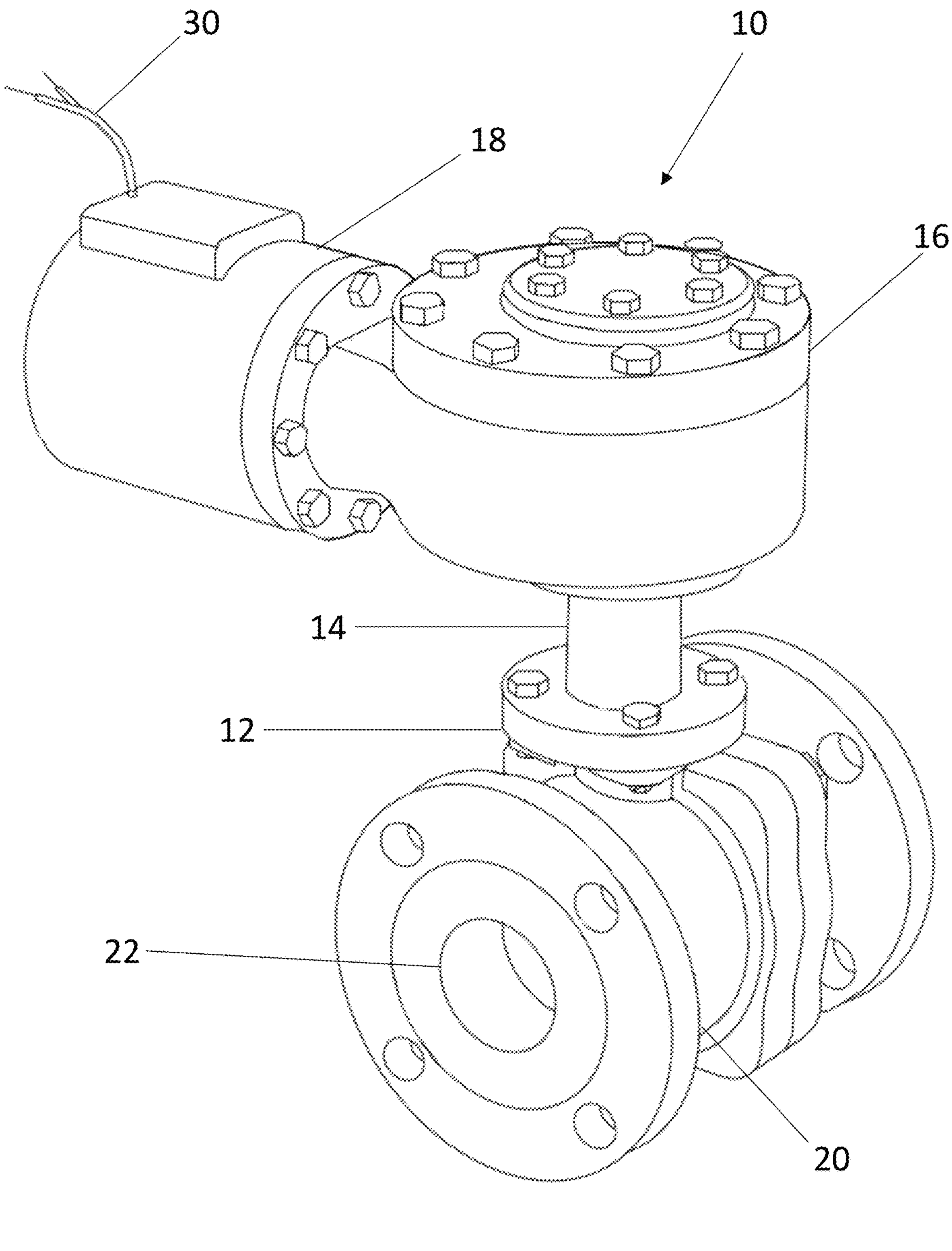


FIG. 1

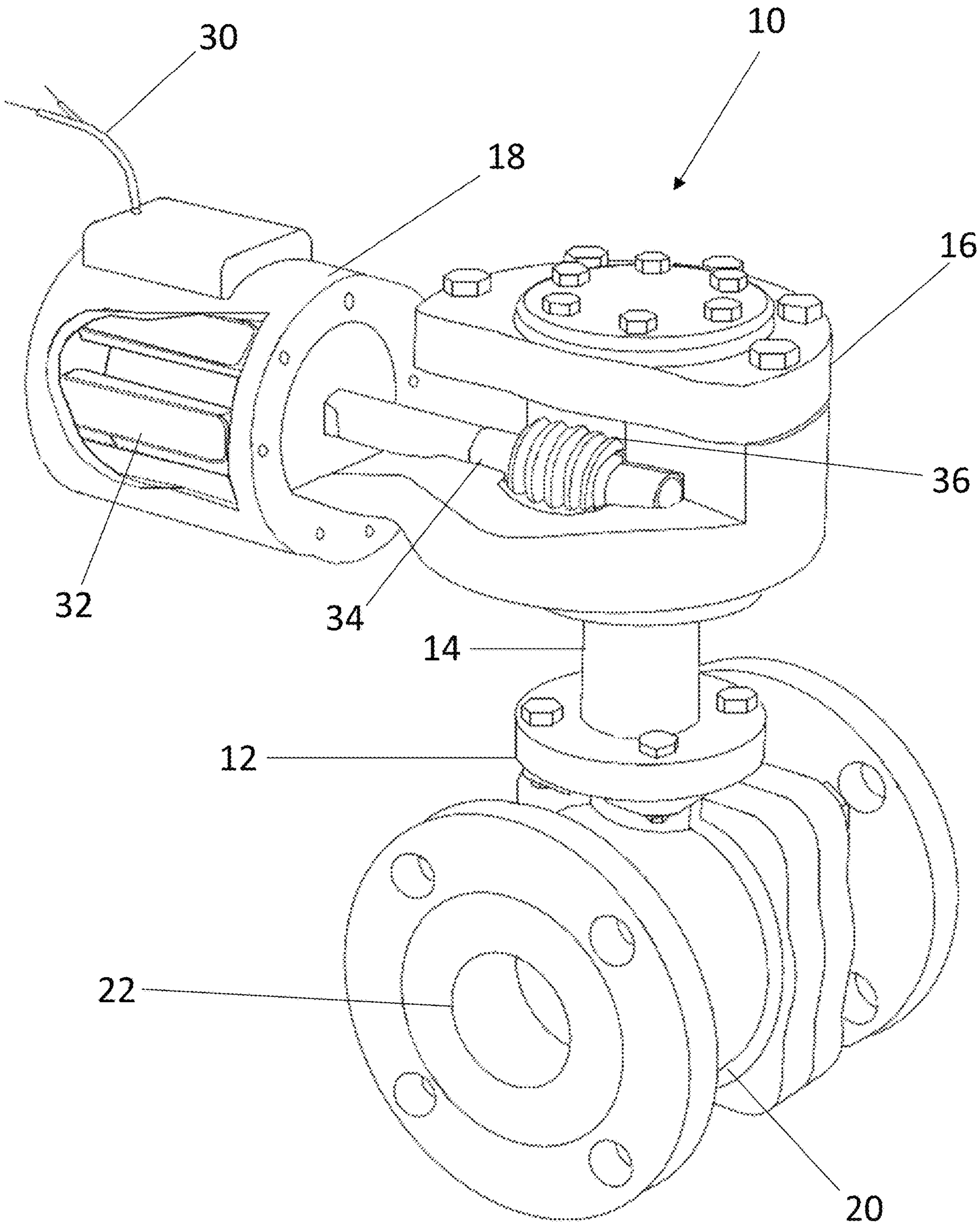


FIG. 2

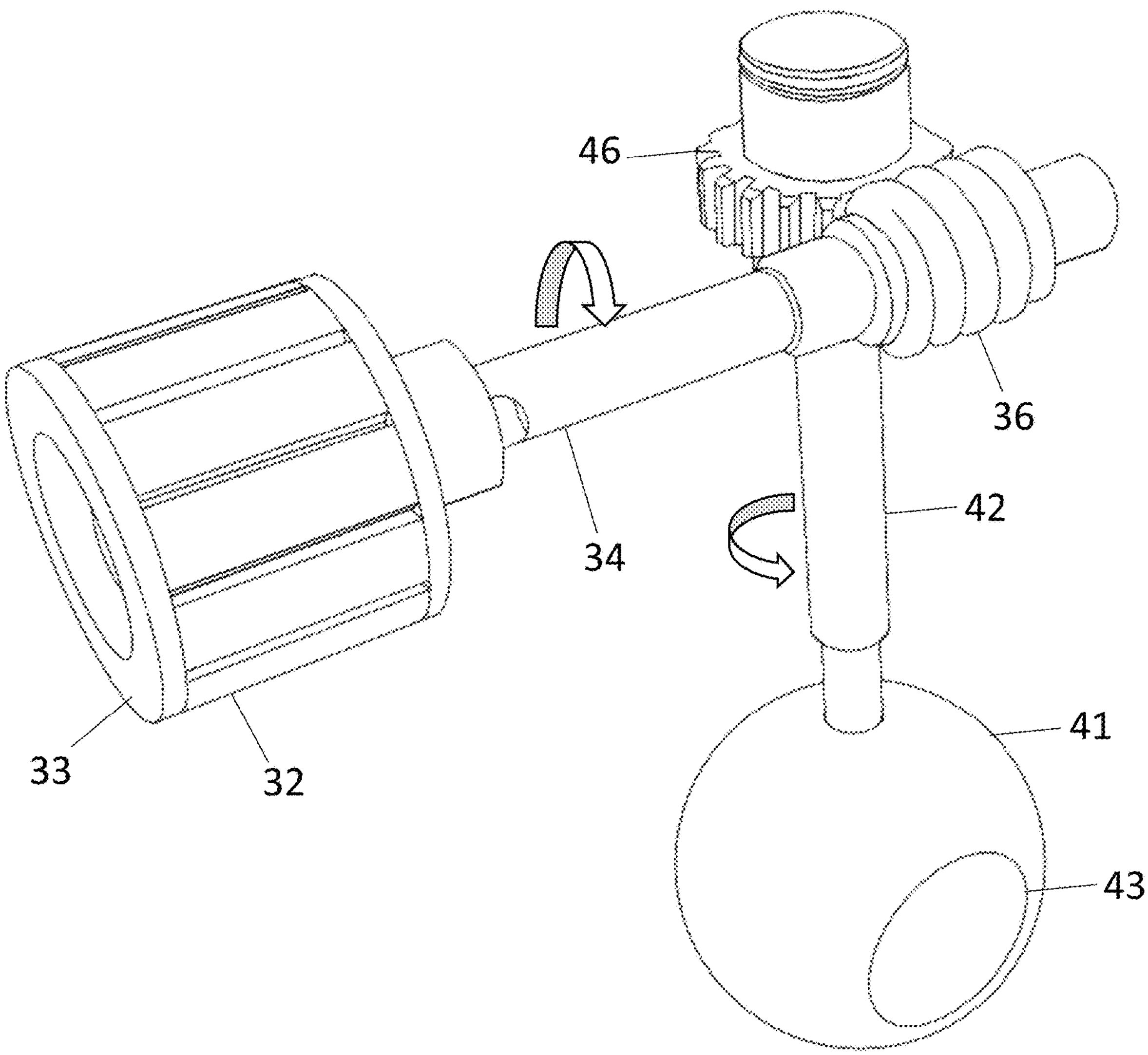


FIG. 3

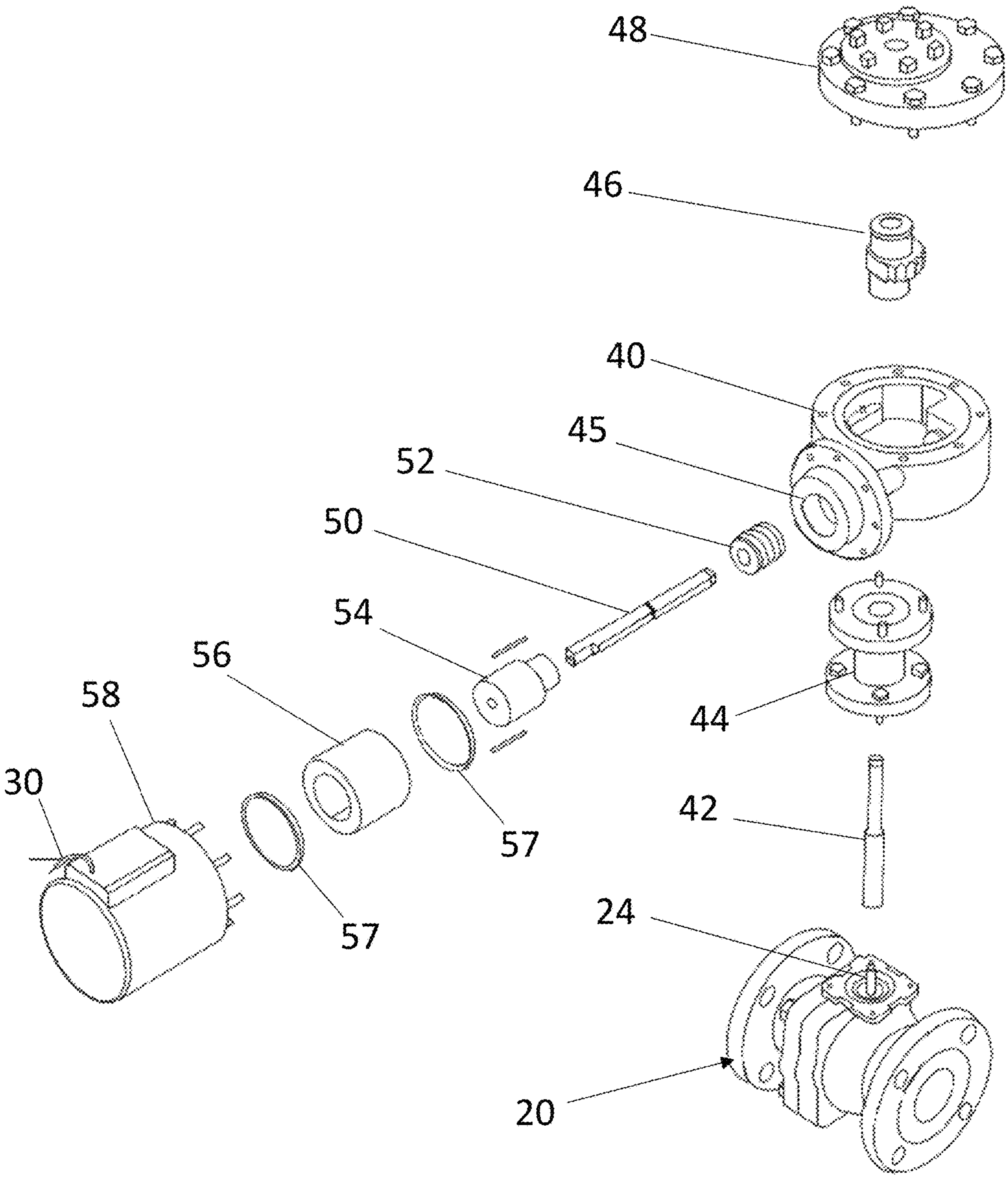


FIG. 4

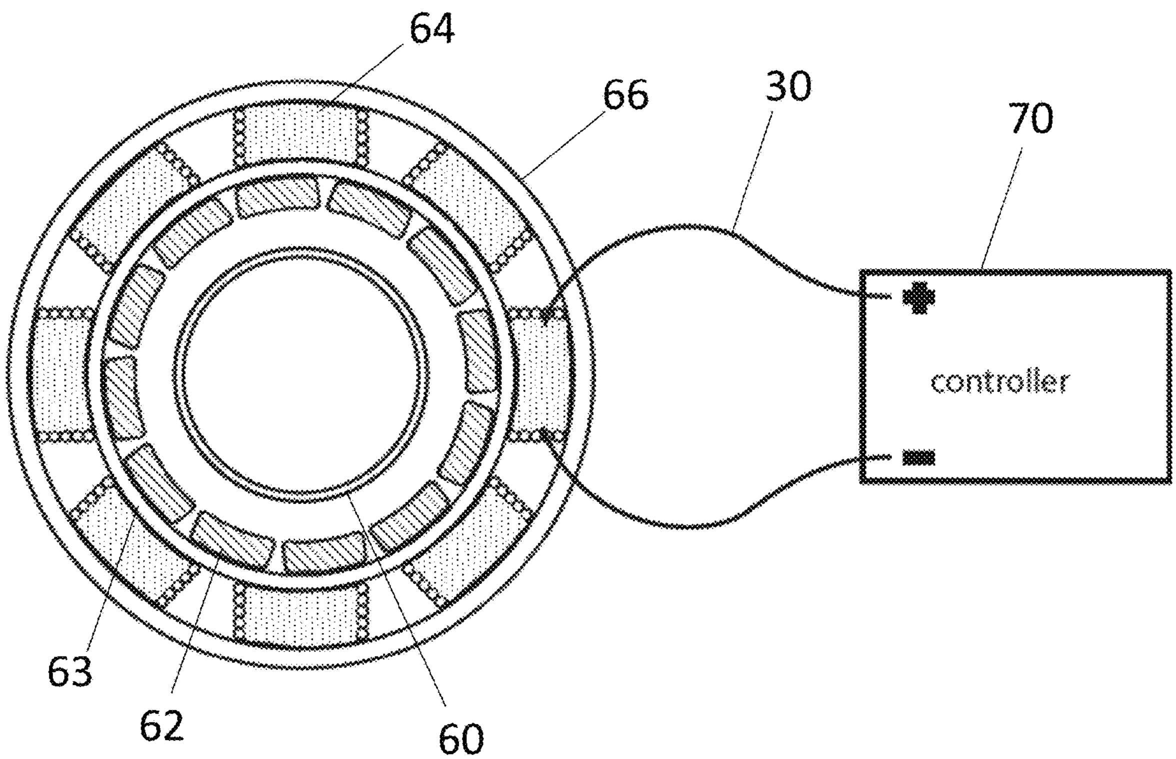
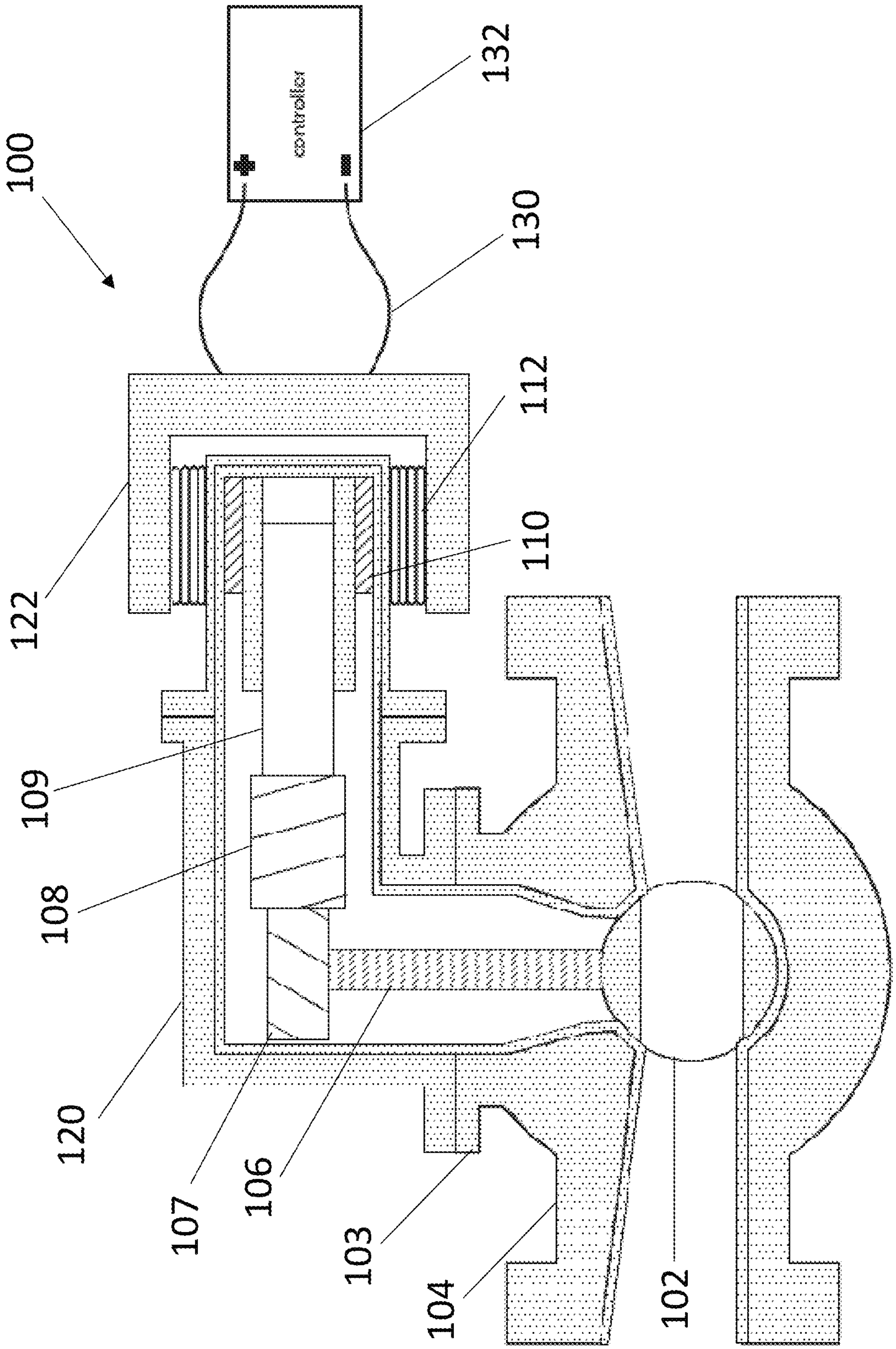


FIG. 5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controller
130
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122
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107
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104
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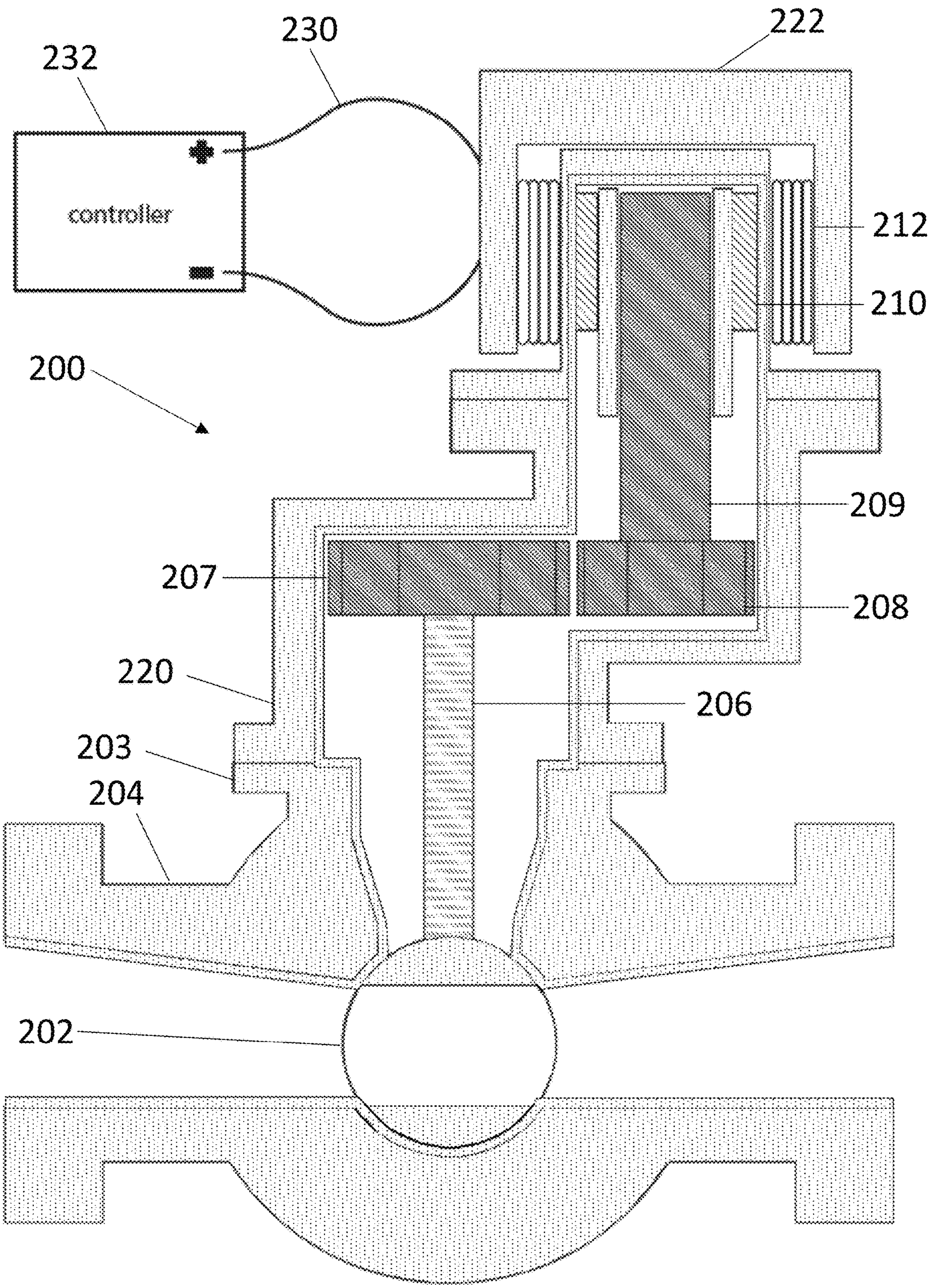
FIG. 6



230
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controller
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FIG. 7

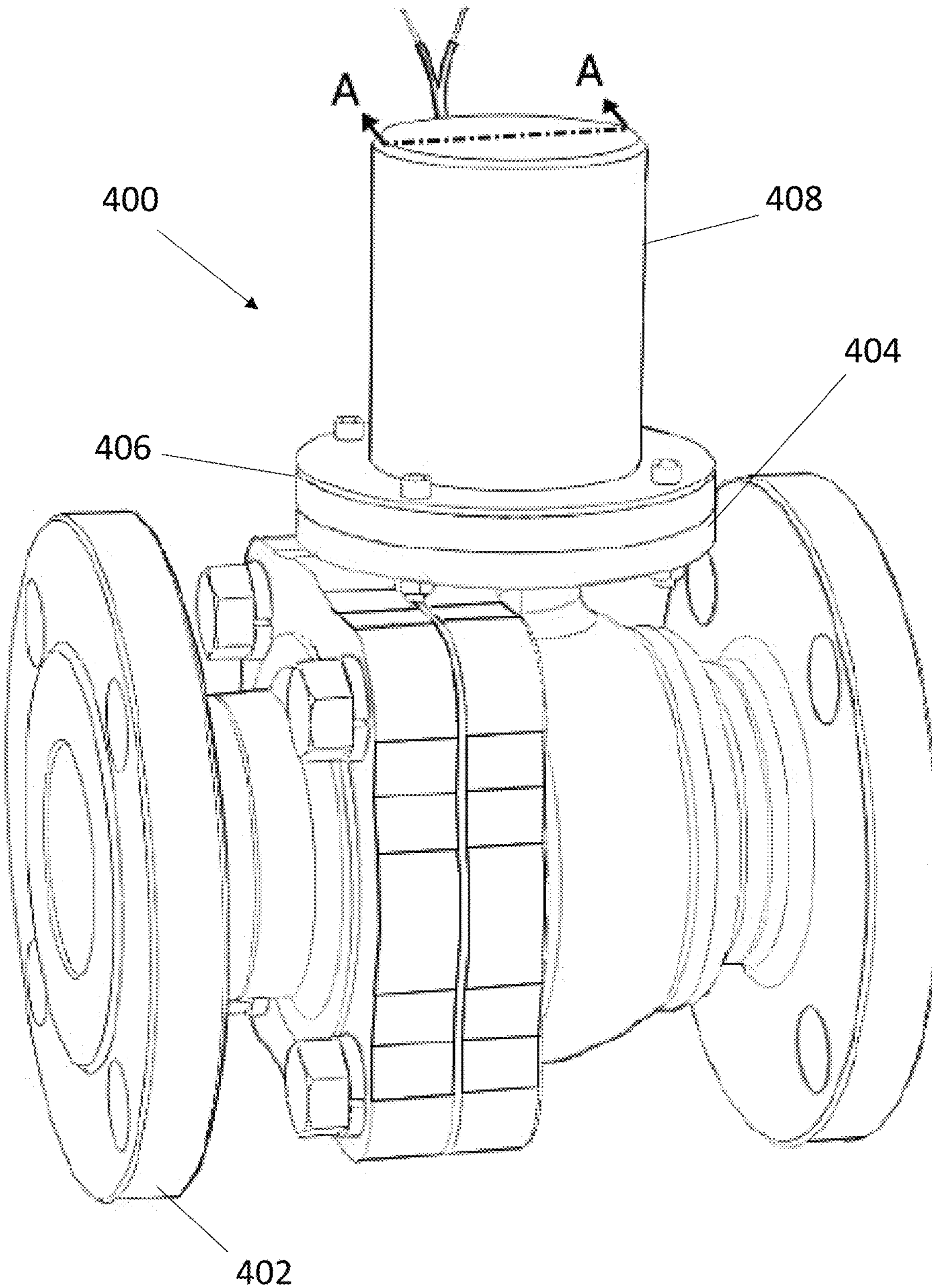


FIG. 8

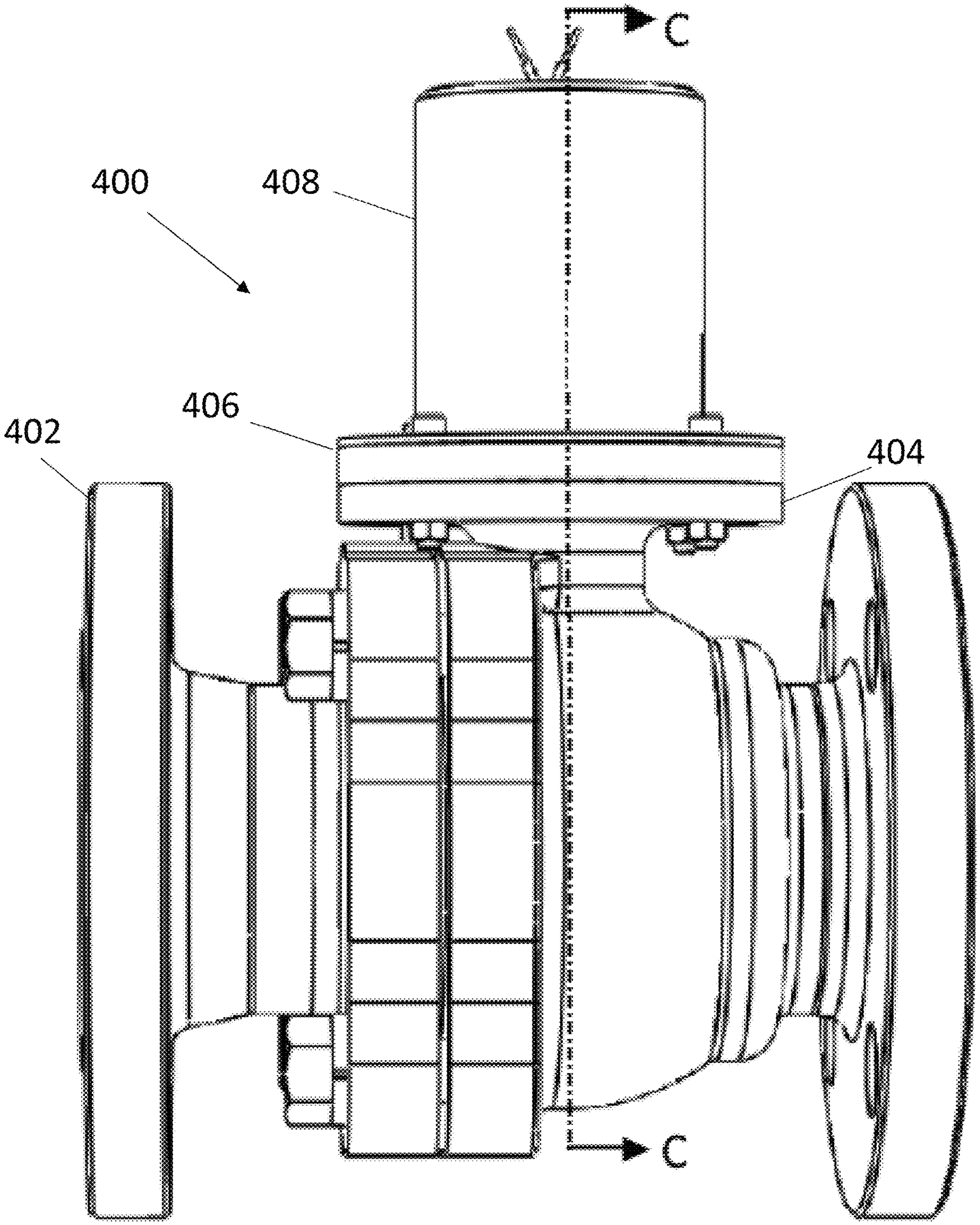


FIG. 9

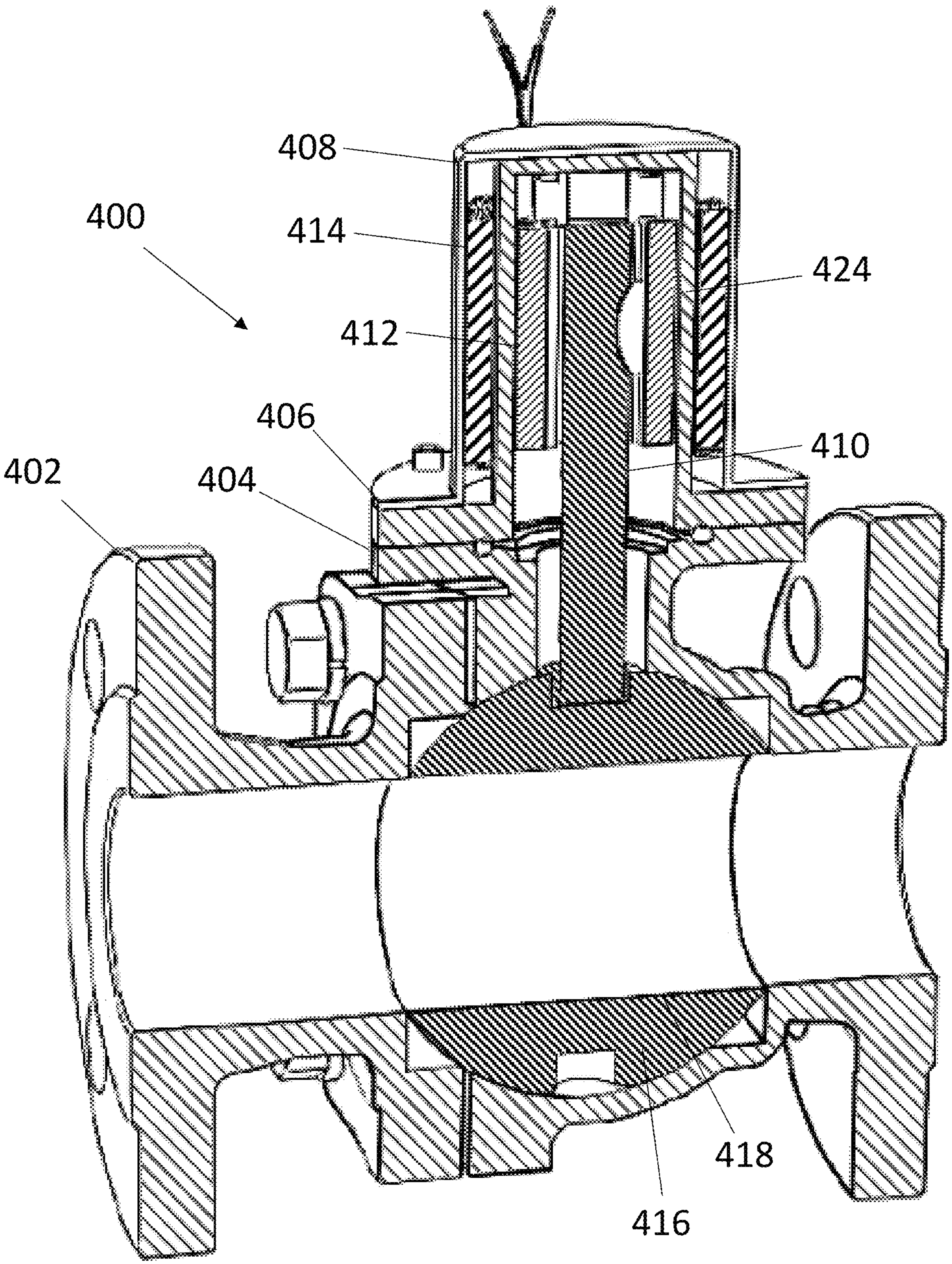


FIG. 10

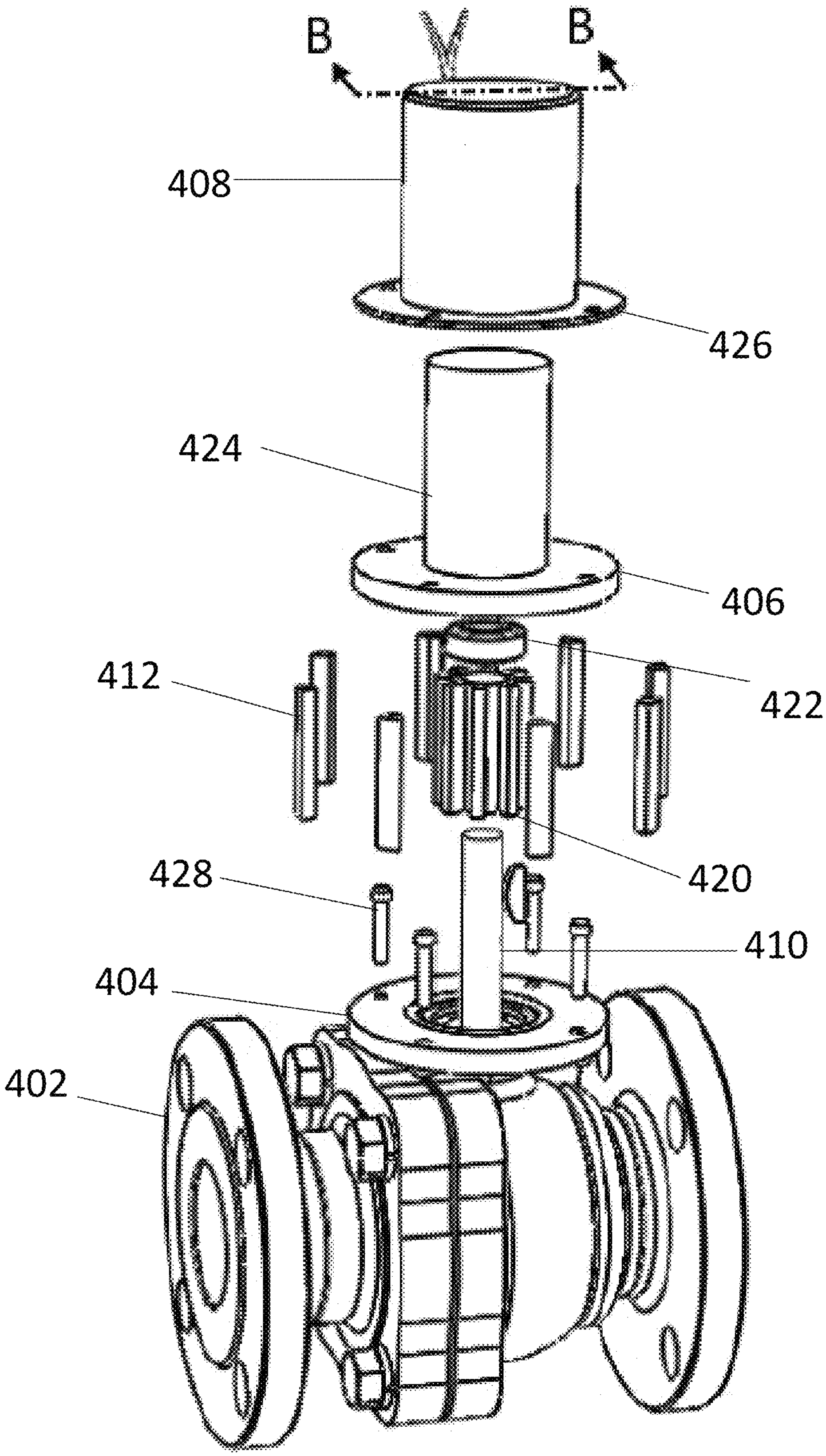


FIG. 11

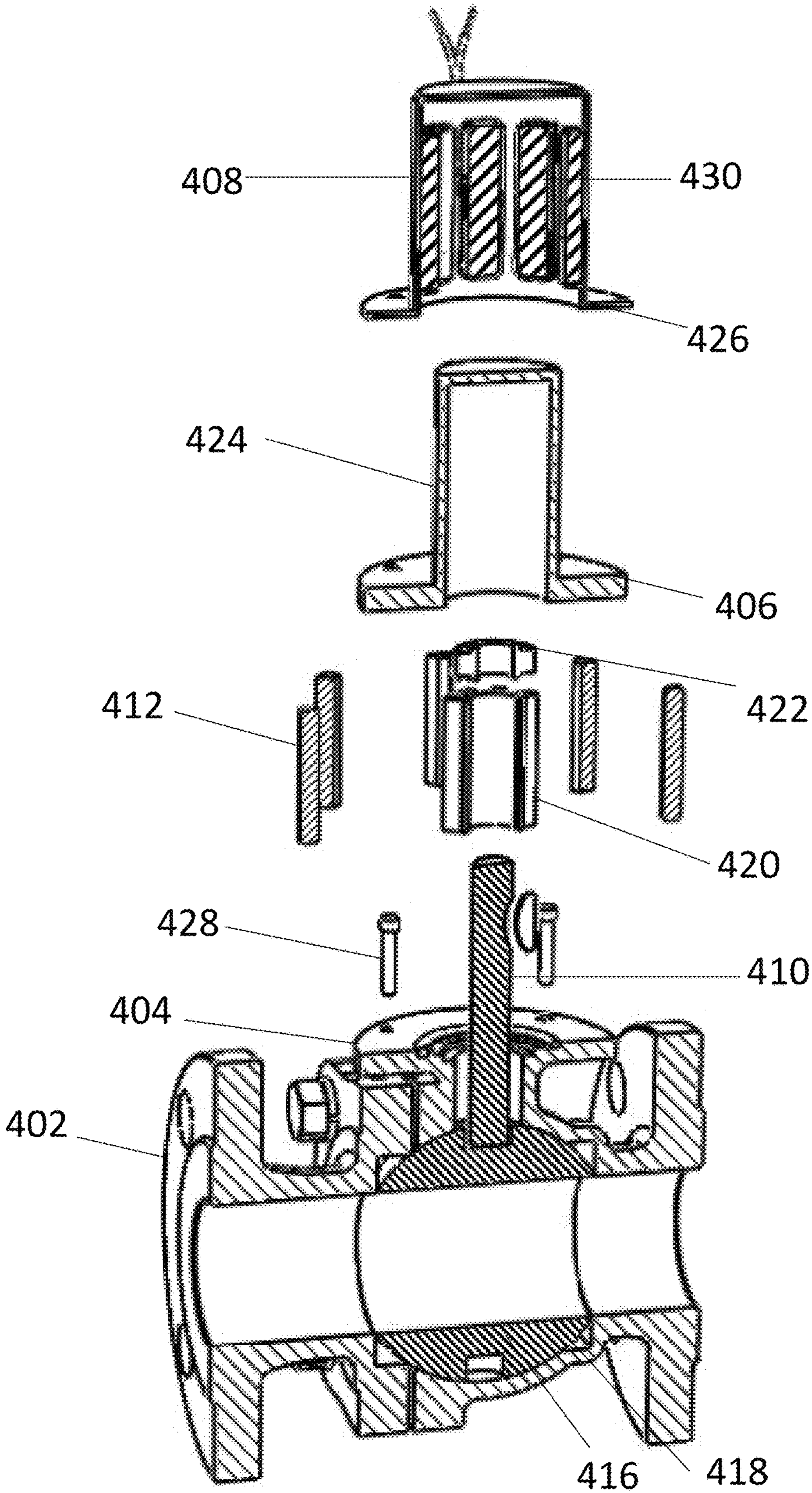


FIG. 12

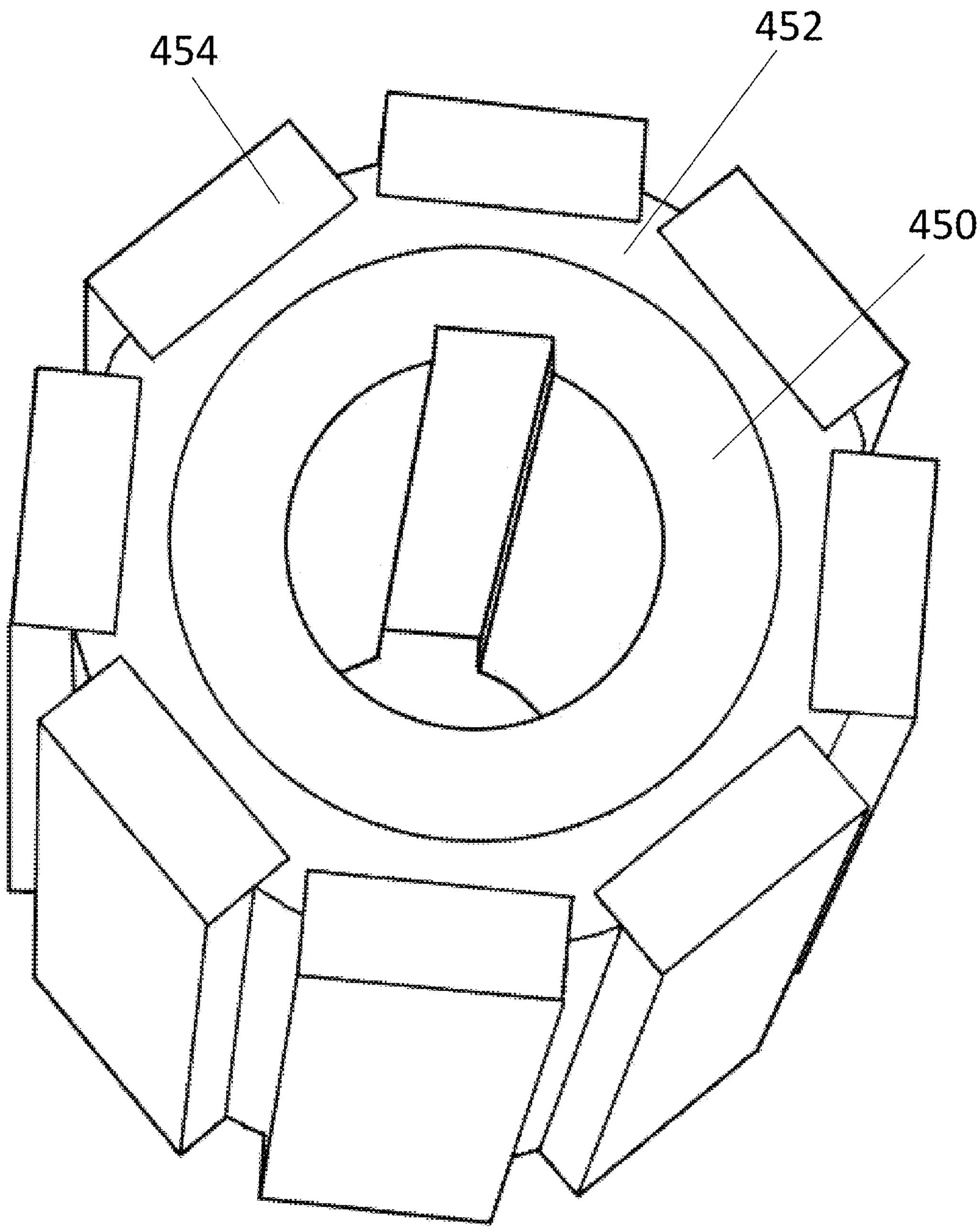


FIG. 13A

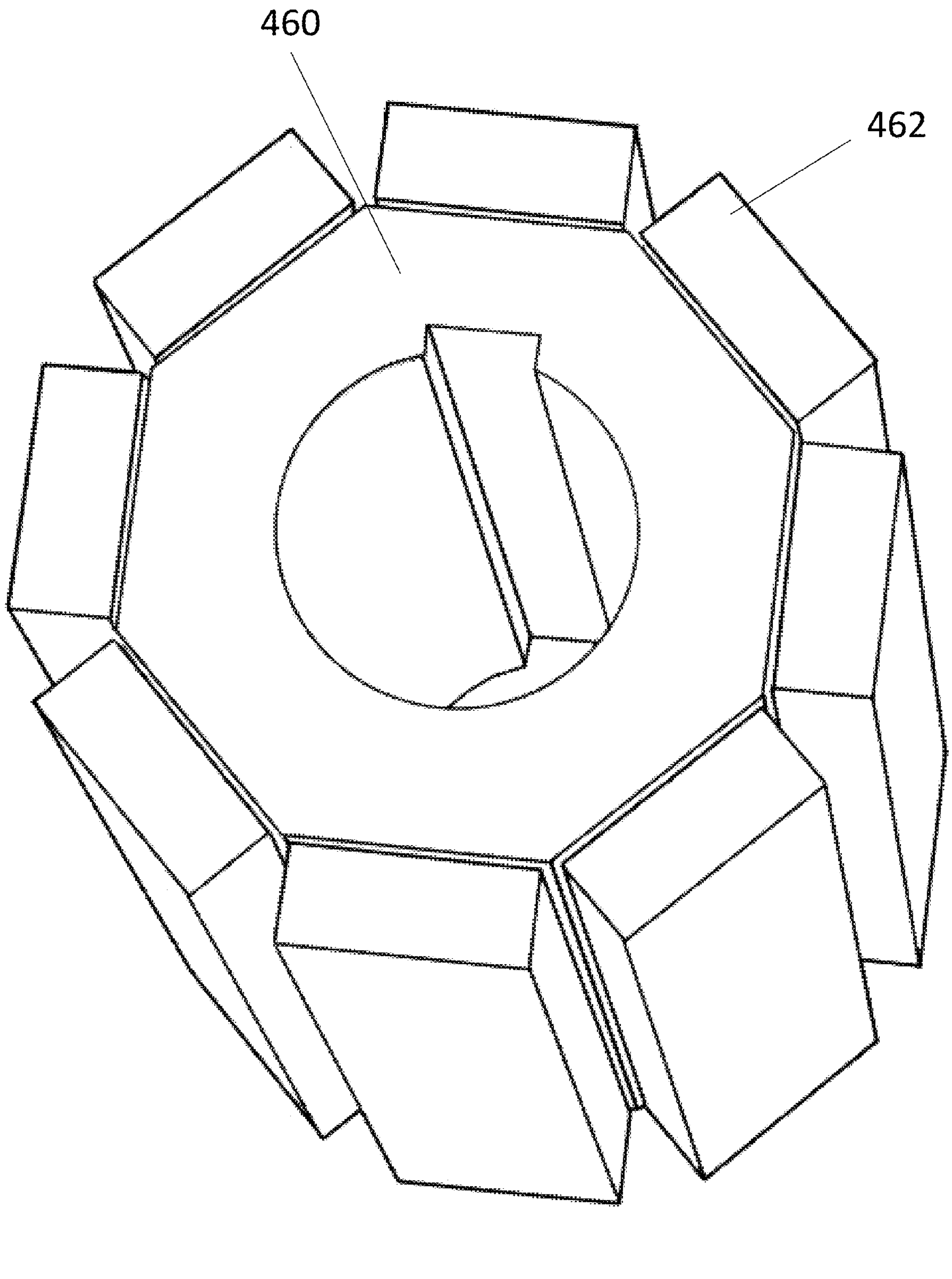


FIG. 13B

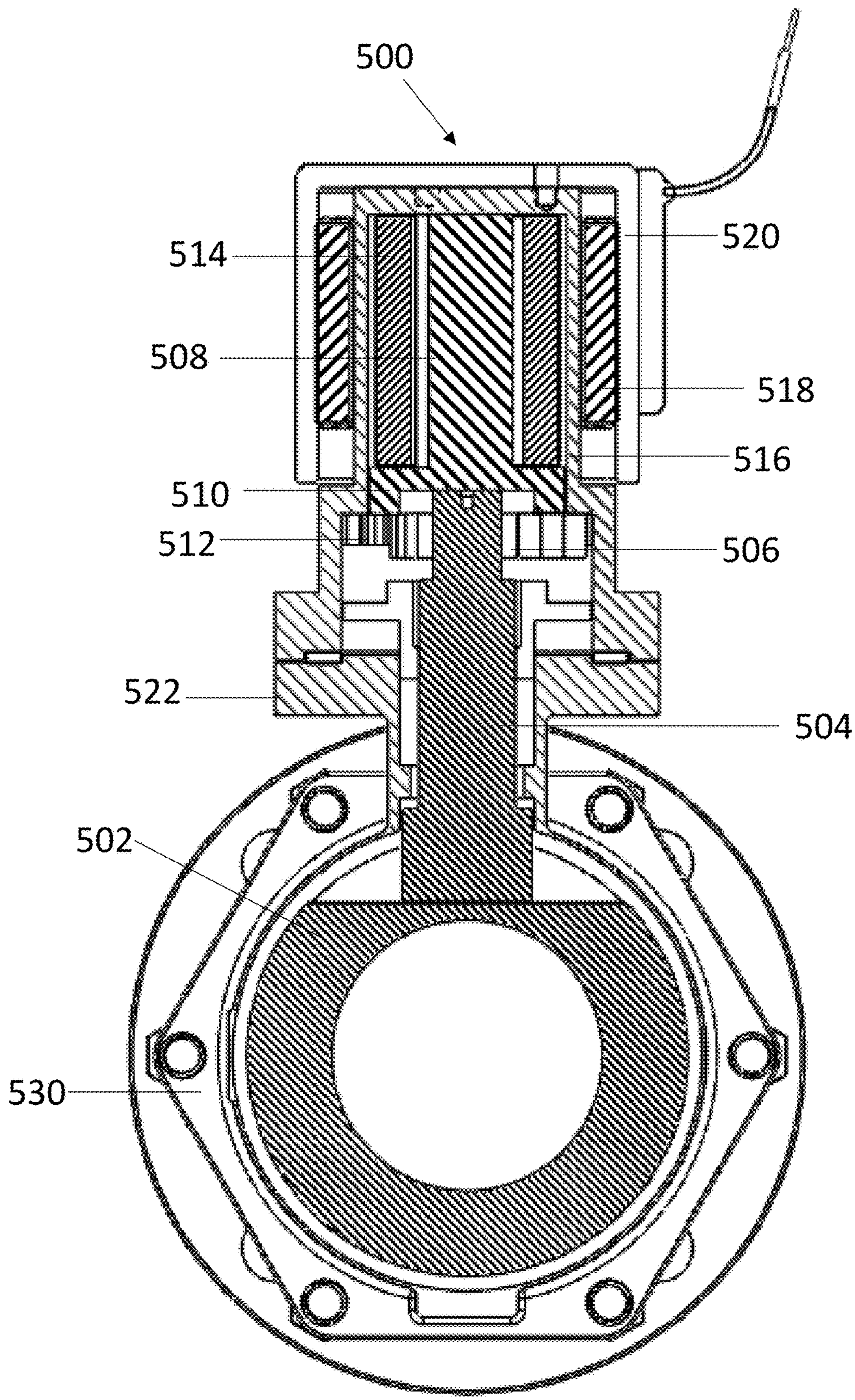


FIG. 14

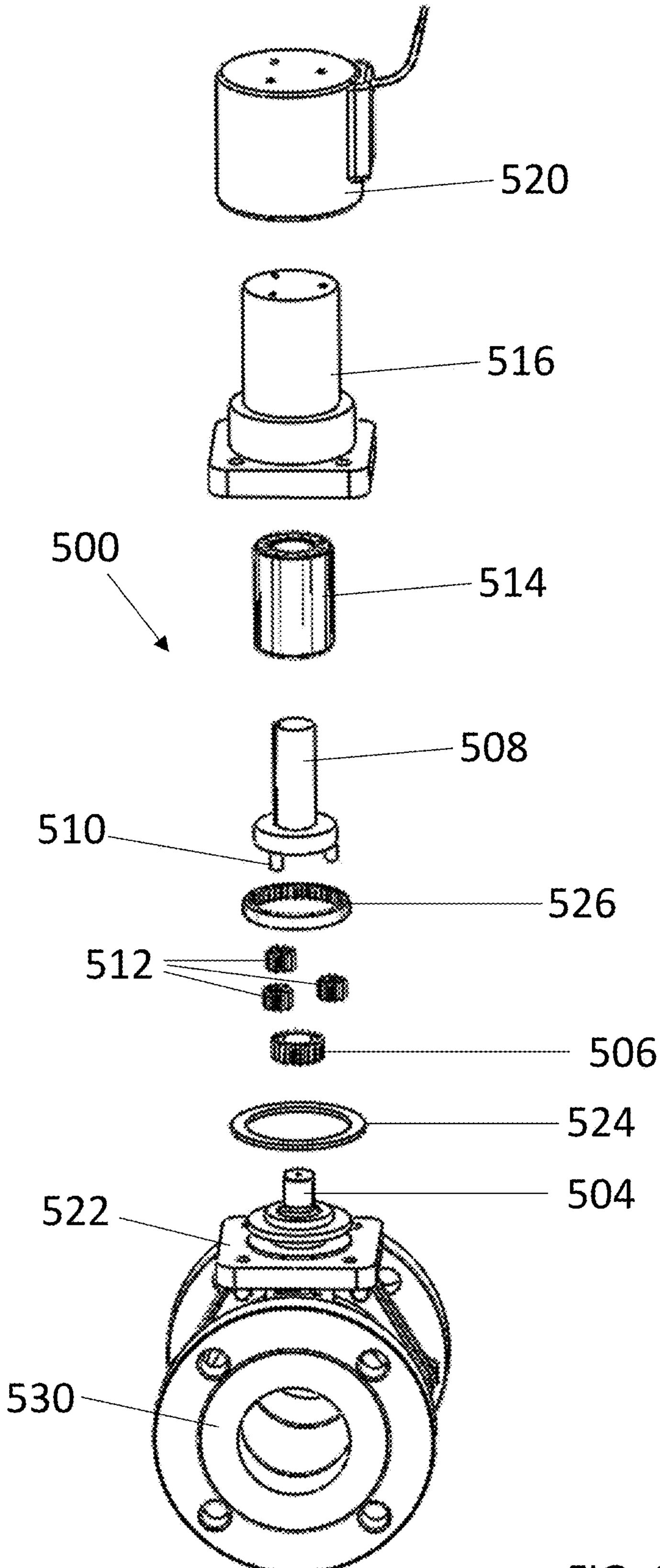
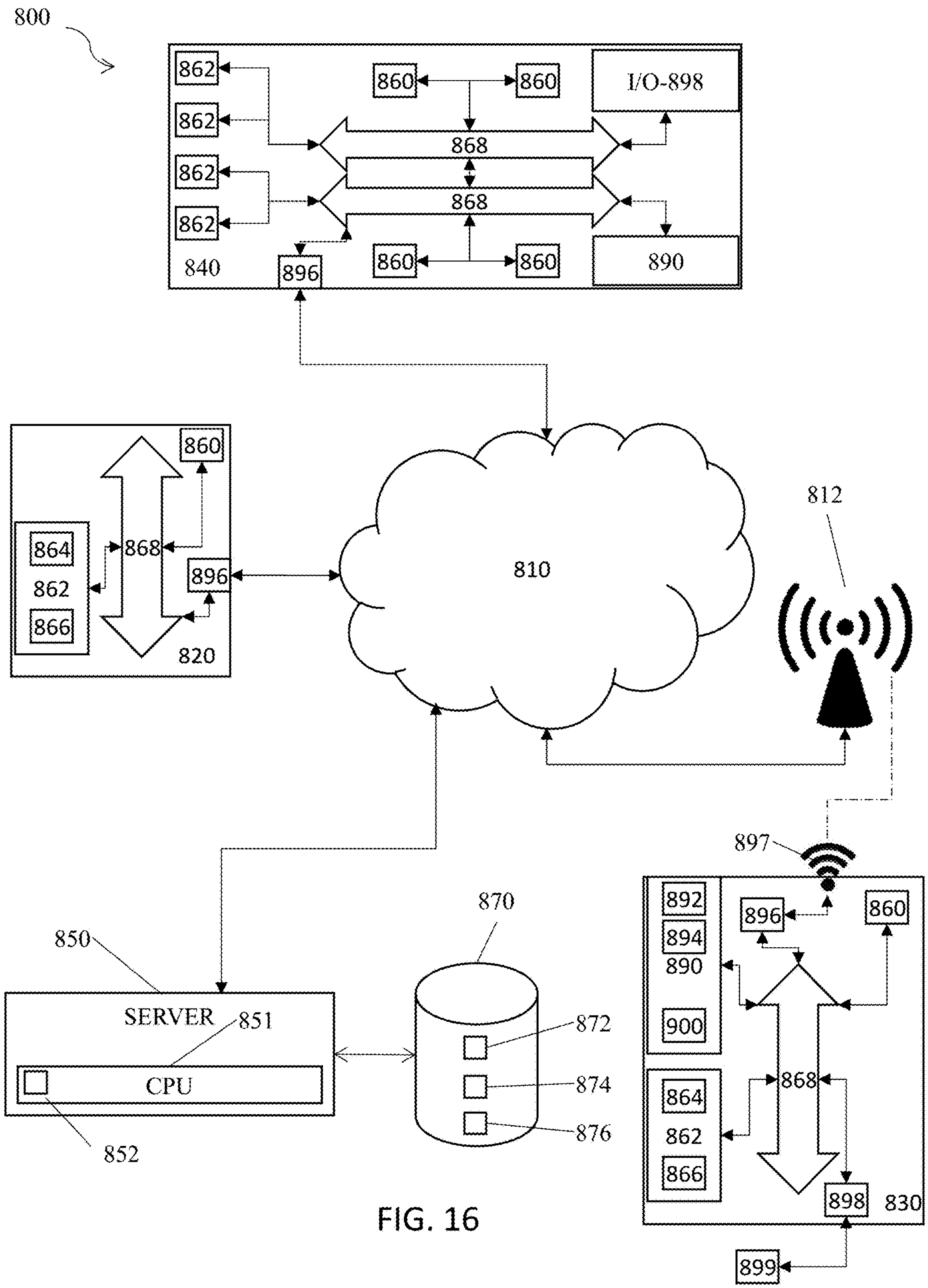


FIG. 15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890
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866
898
830
899
870
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FIG. 16

ELECTROMAGNETICALLY ACTIVATED PIPE VALVE

CROSS REFERENCES TO RELATED APPLICATIONS

This application is related to and claims priority from the following U.S. patents and patent applications. This application is a continuation-in-part of U.S. application Ser. No. 18/096,383, filed Jan. 12, 2023, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to valves especially designed for gas and petroleum lines, and more specifically to electromagnetically operated valves.

2. Description of the Prior Art

It is generally known in the prior art to provide valves for permitting or blocking flow through pipes, including valves using physically rotating magnetic actuation systems.

Prior art patent documents include the following:

U.S. Pat. No. 6,460,567 for Sealed motor driven valve by inventors Hansen et al., filed Nov. 24, 1999 and issued Oct. 8, 2002, discloses a motor operated valve including a valve body with an inlet and outlet and a valve seat therebetween. A valve core reciprocates between open and closed positions by threads of the valve core cooperating with threads on a shaft which rotates with the armature of the motor. The armature has a plurality of spaced apart permanent magnets, a bearing assembly, and is enclosed by a magnetically transparent enclosure closed at one end and hermetically sealed at its other end to the valve body. Lying closely outside the enclosure is a drive stator that includes drive windings and plural Hall-effect devices for commutation of the windings.

U.S. Pat. No. 10,731,770 for Electric flow control valve and actuator by inventors Kawase et al., filed Jul. 7, 2016 and issued Aug. 4, 2020, discloses an actuator including a rod, an electric motor to generate a rotational driving force on supply of electricity, an output shaft to output the rotational driving force of the electric motor to the rod, a feed screw mechanism, and a rotation prevention mechanism. The feed screw mechanism includes a female screw portion formed on one of the output shaft and the rod, and a male screw portion formed on the other to mesh with the female screw portion. The rotation prevention mechanism is configured to regulate rotation of the rod caused by the rotational driving force of the electric motor.

U.S. Pat. No. 7,325,780 for Motor operated valve with reduction gear by inventors Arai et al., filed Dec. 9, 2005 and issued Feb. 5, 2008, discloses a small-sized motor operated valve that has high output and high resolution by housing a reduction gear together with a rotor in a single can. A valve shaft having a valve member is inserted to a motor operated valve body. A rotor is disposed inside a can attached to the body, and inside the rotor is housed a reduction gear. The output of the rotor is input to a sun gear and transmitted to planetary gears. The planetary gears are engaged both with the fixed gear and the output gear, and the output gear is driven at reduced speed by a large reduction ratio. The output of the output gear is transmitted via a driver to a screw shaft, where it is converted into a linear movement and transmitted to the valve shaft.

U.S. Pat. No. 10,221,959 for Higher speed lower torque magnetic valve actuator by inventor Davis, filed Oct. 3, 2018 and issued Mar. 5, 2019, discloses various devices and techniques related to magnetically-actuated valves. In some examples, magnetically-actuated valves may include mechanisms to provide mechanical advantage such that the torques or forces applied to the valve member are higher than the torques or forces transmitted across the sealed valve enclosure by the magnetic coupling. In some examples, valves may employ mechanisms coupled to the external actuator with inverse mechanical advantage that better match traditional or convenient actuation rates of other valves.

U.S. Pat. No. 8,496,228 for Planetary gear ball valve by inventors Burgess et al., filed Jan. 28, 2012 and issued Jul. 30, 2013, discloses a stemless ball valve comprising a first flange, second flange, ball, inner magnetic cartridge, outer magnetic cartridge, and planetary gear assembly. The inner magnetic cartridge is situated inside of the outer magnetic cartridge, and the inner and outer magnetic cartridges actuate the valve. The planetary gear assembly is situated between the inner magnetic cartridge and the ball. The planetary gear assembly comprises one or more planetary gear phases, each planetary gear phase comprising a step-down gear. Each planetary gear phase comprises one or more planetary gears that engage with the inner teeth of the outer ring of the planetary gear assembly and with a step-down gear. The invention further comprises a pressure equalization system comprising inner and outer equalization tubes, a piston situated between the inner and outer equalization tubes, and either a piston spring or spring washer stack that biases the piston in the direction of the clean oil.

US Patent Pub. No. 2013/0140476 for Rotary valve adapter assembly with planetary gear system by inventors Burgess et al., filed Jan. 23, 2012 and published Jun. 6, 2013, discloses a rotary valve adapter assembly comprising an adapter plate configured to attach to a rotary valve body, a torque multiplier assembly comprising one or more planetary gear subassemblies, each of which comprises a sun gear, ring gear, and a plurality of planetary gears, a magnetic actuator assembly comprising two sets of magnetically coupled magnets, and a shaft. The magnetic actuator assembly interfaces with the torque multiplier assembly such that when the magnets of the magnetic actuator assembly rotate, they cause the sun gear of a first planetary gear subassembly to rotate and the planetary gears to walk on the ring gear. The shaft interfaces with the carrier of one of the planetary gear subassemblies such that when the carrier rotates, the shaft also rotates, thereby causing the valve to open and close. The assembly further comprises a pressure equalization system comprising a piston and piston spring or spring washer stack.

U.S. Pat. No. 9,377,121 for Leak-free rotary valve with internal worm gear by inventors Burgess et al., filed Nov. 18, 2012 and issued Jun. 28, 2016, discloses a rotary valve assembly composing a leak-free enclosure containing a worm gear and a pinion gear, an adapter plate that is situated between a rotary valve body and the enclosure and that secures the rotary valve body to the enclosure, and a magnetic actuator assembly. The worm gear engages with the pinion gear such that when the worm gear rotates, the pinion gear rotates as well. The enclosure is situated between the magnetic actuator assembly and the rotary valve body. A shaft extends through the center of the pinion gear and causes a valve within the rotary valve body to open and close based on rotation of the shaft. In an alternate embodiment, the invention is a rotary valve as described above with an integral adapter plate.

U.S. Pat. No. 7,971,855 for Stemless ball valve by inventors Burgess et al., filed Dec. 9, 2008 and issued Jul. 5, 2011, discloses a stemless ball valve comprising two flanges and a ball with a channel, two axis pins and two travel pins. One end of each axis and travel pin is fixedly attached to the ball, and the other end of each axis pin is lodged into a notch in the first or second flange such that the axis pin is allowed to rotate in the notch. The guide sleeve comprises two channels, and one end of each travel pin is situated within one of the two channels in the guide sleeve. An outer magnetic cartridge causes the inner magnetic cartridge and guide sleeve to rotate, and when the guide sleeve rotates, the travel pins move up and down within the channels in the guide sleeve. The movement of the travel pins within the channels in the guide sleeve causes the ball to rotate, thereby opening and closing the ball valve.

U.S. Pat. No. 6,848,401 for Valve timing adjusting device by inventors Takenaka et al., filed Apr. 21, 2003 and issued Feb. 1, 2005, discloses a valve timing adjusting device adjusting valve timing by shifting rotational phase of a camshaft relative to a crankshaft. The device has an electric motor for rotating a rotor member that drives and moves a phase defining member to a required position. The phase defining member defines the rotational phase of the camshaft in accordance with the position itself. The phase defining member may be a planetary gear rotatably supported on an eccentric shaft as the rotor member. The planetary gear works as both a reduction mechanism and a phase shifting mechanism. The phase defining member may be a control pin slidably supported on a rotatable member as the rotor member. A planetary gear may be additionally used as the reduction mechanism for rotating the rotatable member. It is possible to control the phase with high accuracy and durability.

SUMMARY OF THE INVENTION

The present invention relates to valves especially designed for gas and petroleum lines, and more specifically to electromagnetically operated valves.

It is an object of this invention to electromagnetically actuate a valve mechanism without requiring the mechanism to rotate a first set of magnets around a second set of magnets.

In one embodiment, the present invention is directed to an electromagnetically actuated valve system, including at least one valve blocking mechanism positioned within a pipe, wherein, in an open position, the at least one valve blocking mechanism substantially allows fluid flow through the pipe, and wherein, in a closed position, the at least one valve blocking mechanism substantially prohibits fluid through the pipe, a valve stem mechanically coupled with the at least one valve blocking mechanism, such that rotation of the valve stem causes the at least one valve blocking mechanism to change between the open position, the closed position, and one or more semi-open positions between the open position and the closed position, a center gear attached to a stop of the valve stem, an actuator stem, connected to a plurality of planet gears, configured to intermesh with the center gear of the valve stem, one or more permanent magnets surrounding a section of the actuator stem, a valve housing sealingly enclosing the at least one valve blocking mechanism, the valve stem, the actuator stem, the center gear, the plurality of planet gears, and the one or more permanent magnets, wherein the valve housing includes at least one magnetic containment chamber surrounding the one or more permanent magnets, at least one electromagnet connected to an external surface of the at least one magnetic containment chamber, and a controller electrically connected to the at least one electromagnet, wherein the controller alternates the at least one valve blocking mechanism between the open position, the closed position, and the one or more semi-open positions by activating the at least one electromagnet, and wherein the magnetic containment chamber is formed from at least one substantially non-ferromagnetic material.

In another embodiment, the present invention is directed to an electromagnetically actuated valve system, including at least one valve blocking mechanism positioned within a pipe, wherein, in an open position, the at least one valve blocking mechanism substantially allows fluid flow through the pipe, and wherein, in a closed position, the at least one valve blocking mechanism substantially prohibits fluid through the pipe, a valve stem mechanically coupled with the at least one valve blocking mechanism, such that rotation of the valve stem causes the at least one valve blocking mechanism to change between the open position, the closed position, and one or more semi-open positions between the open position and the closed position, a center gear attached to a stop of the valve stem, an actuator stem, connected to a plurality of planet gears, configured to intermesh with the center gear of the valve stem, one or more permanent magnets embedded in a magnetic carrier surrounding a section of the actuator stem, a valve housing sealingly enclosing the at least one valve blocking mechanism, the valve stem, the actuator stem, the center gear, the plurality of planet gears, and the one or more permanent magnets, wherein the valve housing includes at least one magnetic containment chamber surrounding the one or more permanent magnets, at least one electromagnet connected to an external surface of the at least one magnetic containment chamber, and a controller electrically connected to the at least one electromagnet, wherein the controller alternates the at least one valve blocking mechanism between the open position, the closed position, and the one or more semi-open positions by activating the at least one electromagnet, and wherein the at least one electromagnet does not physically rotate relative to the at least one magnetic containment chamber during actuation of the system.

In yet another embodiment, the present invention is directed to an electromagnetically actuated valve system, including at least one valve blocking mechanism positioned within a pipe, wherein, in an open position, the at least one valve blocking mechanism substantially allows fluid flow through the pipe, and wherein, in a closed position, the at least one valve blocking mechanism substantially prohibits fluid through the pipe, a valve stem mechanically coupled with the at least one valve blocking mechanism, such that rotation of the valve stem causes the at least one valve blocking mechanism to change between the open position, the closed position, and one or more semi-open positions between the open position and the closed position, a center gear attached to a stop of the valve stem, an actuator stem, connected to a plurality of planet gears, configured to intermesh with the center gear of the valve stem, one or more permanent magnets surrounding a section of the actuator stem, a valve housing sealingly enclosing the at least one valve blocking mechanism, the valve stem, the actuator stem, the center gear, the plurality of planet gears, and the one or more permanent magnets, wherein the valve housing includes at least one magnetic containment chamber surrounding the one or more permanent magnets, at least one electromagnet connected to an external surface of the at least one magnetic containment chamber, and a controller electrically connected to the at least one electromagnet, an outer magnetic housing surrounding the at least one electromagnet, wherein the controller alternates the at least one valve blocking mechanism between the open position, the closed position, and the one or more semi-open positions by activating the at least one electromagnet, and wherein the actuator stem and the valve stem are substantially parallel and collinear.

These and other aspects of the present invention will become apparent to those skilled in the art after a reading of the following description of the preferred embodiment when considered with the drawings, as they support the claimed invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an isometric view of an electromagnetic valve according to one embodiment of the present invention.

FIG. **2** illustrates an isometric view of an electromagnetic valve with an external section of the valve removed, providing a view of internal components according to one embodiment of the present invention.

FIG. **3** illustrates a transparent view of internal components of an electromagnetic valve according to one embodiment of the present invention.

FIG. **4** illustrates an isometric exploded view of an electromagnetic valve according to one embodiment of the present invention.

FIG. **5** illustrates a top sectional view of an electromagnetic valve according to one embodiment of the present invention.

FIG. **6** illustrates a side sectional view of an electromagnetic valve including a worm drive and a quarter-turn valve according to one embodiment of the present invention.

FIG. **7** illustrates a side sectional view of an electromagnetic valve including a parallel shaft gear mechanism and a quarter-turn valve according to one embodiment of the present invention.

FIG. **8** illustrates a perspective view of an electromagnetic valve according to one embodiment of the present invention.

FIG. **9** illustrates an orthogonal side view of an electromagnetic valve according to one embodiment of the present invention.

FIG. **10** illustrates a perspective sectional view taken along the line A-A of FIG. **8** according to one embodiment of the present invention.

FIG. **11** illustrates an exploded view of an electromagnetic valve according to one embodiment of the present invention.

FIG. **12** illustrates an exploded sectional view taken along the line B-B of FIG. **11** according to one embodiment of the present invention.

FIG. **13**A illustrates a perspective view of a magnetic carrier according to one embodiment of the present invention.

FIG. **13**B illustrates a perspective view of an actuator stem collar with permanent magnets directed attached to it according to one embodiment of the present invention.

FIG. **14** illustrates a side sectional view taken along the line C-C of FIG. **9** according to one embodiment of the present invention.

FIG. **15** illustrates a perspective exploded view of an electromagnetic quarter-turn valve utilizing a planetary gear mechanism according to one embodiment of the present invention.

FIG. **16** is a schematic diagram of a system of the present invention.

DETAILED DESCRIPTION

The present invention is generally directed to valves especially designed for gas and petroleum lines, and more specifically to electromagnetically operated valves.

In one embodiment, the present invention is directed to an electromagnetically actuated valve system, including at least one valve blocking mechanism positioned within a pipe, wherein, in an open position, the at least one valve blocking mechanism substantially allows fluid flow through the pipe, and wherein, in a closed position, the at least one valve blocking mechanism substantially prohibits fluid through the pipe, a valve stem mechanically coupled with the at least one valve blocking mechanism, such that rotation of the valve stem causes the at least one valve blocking mechanism to change between the open position, the closed position, and one or more semi-open positions between the open position and the closed position, a center gear attached to a stop of the valve stem, an actuator stem, connected to a plurality of planet gears, configured to intermesh with the center gear of the valve stem, one or more permanent magnets surrounding a section of the actuator stem, a valve housing sealingly enclosing the at least one valve blocking mechanism, the valve stem, the actuator stem, the center gear, the plurality of planet gears, and the one or more permanent magnets, wherein the valve housing includes at least one magnetic containment chamber surrounding the one or more permanent magnets, at least one electromagnet connected to an external surface of the at least one magnetic containment chamber, and a controller electrically connected to the at least one electromagnet, wherein the controller alternates the at least one valve blocking mechanism between the open position, the closed position, and the one or more semi-open positions by activating the at least one electromagnet, and wherein the magnetic containment chamber is formed from at least one substantially non-ferromagnetic material.

In another embodiment, the present invention is directed to an electromagnetically actuated valve system, including at least one valve blocking mechanism positioned within a pipe, wherein, in an open position, the at least one valve blocking mechanism substantially allows fluid flow through the pipe, and wherein, in a closed position, the at least one valve blocking mechanism substantially prohibits fluid through the pipe, a valve stem mechanically coupled with the at least one valve blocking mechanism, such that rotation of the valve stem causes the at least one valve blocking mechanism to change between the open position, the closed position, and one or more semi-open positions between the open position and the closed position, a center gear attached to a stop of the valve stem, an actuator stem, connected to a plurality of planet gears, configured to intermesh with the center gear of the valve stem, one or more permanent magnets embedded in a magnetic carrier surrounding a section of the actuator stem, a valve housing sealingly enclosing the at least one valve blocking mechanism, the valve stem, the actuator stem, the center gear, the plurality of planet gears, and the one or more permanent magnets, wherein the valve housing includes at least one magnetic containment chamber surrounding the one or more permanent magnets, at least one electromagnet connected to an external surface of the at least one magnetic containment chamber, and a controller electrically connected to the at least one electromagnet, wherein the controller alternates the at least one valve blocking mechanism between the open position, the closed position, and the one or more semi-open positions by activating the at least one electromagnet, and wherein the at least one electromagnet does not physically rotate relative to the at least one magnetic containment chamber during actuation of the system.

In yet another embodiment, the present invention is directed to an electromagnetically actuated valve system, including at least one valve blocking mechanism positioned within a pipe, wherein, in an open position, the at least one valve blocking mechanism substantially allows fluid flow through the pipe, and wherein, in a closed position, the at least one valve blocking mechanism substantially prohibits fluid through the pipe, a valve stem mechanically coupled with the at least one valve blocking mechanism, such that rotation of the valve stem causes the at least one valve blocking mechanism to change between the open position, the closed position, and one or more semi-open positions between the open position and the closed position, a center gear attached to a stop of the valve stem, an actuator stem, connected to a plurality of planet gears, configured to intermesh with the center gear of the valve stem, one or more permanent magnets surrounding a section of the actuator stem, a valve housing sealingly enclosing the at least one valve blocking mechanism, the valve stem, the actuator stem, the center gear, the plurality of planet gears, and the one or more permanent magnets, wherein the valve housing includes at least one magnetic containment chamber surrounding the one or more permanent magnets, at least one electromagnet connected to an external surface of the at least one magnetic containment chamber, and a controller electrically connected to the at least one electromagnet, an outer magnetic housing surrounding the at least one electromagnet, wherein the controller alternates the at least one valve blocking mechanism between the open position, the closed position, and the one or more semi-open positions by activating the at least one electromagnet, and wherein the actuator stem and the valve stem are substantially parallel and collinear.

In order to prevent leakage of potentially harmful fluids, it is important that many pipelines (e.g., oil and gas pipelines, pipelines holding noxious chemicals, cryogenic hydrogen or helium pipelines) remain fully sealed. Preventing leakage requires reliable valve mechanisms that both allow an operator to halt flow of fluid through the pipeline and which prevent leakage of the fluid through the valve mechanism.

At the point where current valves are attached to a pipe, typically a stem is attached to a valve mechanism within the pipe (e.g., gate valve, globe valve, plug valve, ball valve, butterfly valve, needle valve, etc.). A handle is then attached to the stem such that an operator is able to turn the handle in order to open or close the valve. In order to prevent fluid flowing within the pipe from leaking, it is required to tightly seal the area where the stem rises through the side wall of the pipe. Typically, seals, sometimes called packing, take the form of gaskets, or O-rings, surrounding the stem of the valve. However, especially in high pressure situation as with oil and natural gas pipelines, these O-rings tend to fail over time and begin to allow some leakage. Occasionally, these leaks are catastrophic and cause fluid loss and frequently causing environmental damage and health care risks. Therefore, a more reliable method is needed to prevent fluid leakage from valves.

Solenoid valves are known in the art. Solenoid valves use an electromagnet (e.g., the solenoid) surrounding a movable permanent magnetic (e.g., ferromagnetic) core, where activation of the solenoid by application of electric current causes the permanent ferromagnetic core to move, thereby opening or close the valve. However, a fault of current solenoidal valves is that most lack the ability to apply sufficient torque in order to be used in larger, higher pressure pipelines, such as oil and natural gas pipelines.

Previous inventions, such as U.S. Pat. No. 8,496,228, have used magnetic means for turning valves, including quarter-turn valves, such as U.S. Pat. No. 9,377,121, planetary gear ball valves, such as described in U.S. Pat. No. 8,496,228, and rising stem valves, such as described in U.S. Pat. No. 9,702,469. However, each of these prior art inventions have required physical rotation (either manually or automatically by means of a controller) of an outer shell including a plurality of electromagnets relative to an inner shell of permanent magnets attached to a valve shaft. However, systems that require physical rotation are not always preferred. Physical rotation, for example, gradually causes wear in the interface between rotating components. Furthermore, physical rotation typically requires more space for the component to able to move, not allowing other components to be tightly packed against the rotating component. Therefore, for some instances, a system for electromagnetically actuating a valve without physical rotation of the components is needed.

Additionally, some previous systems that have incorporated magnetic actuation systems, in valves or in other fields, include only an outer magnetic mechanism, but not an internal magnetic coupled with the stem, leading to lower torque.

Referring now to the drawings in general, the illustrations are for the purpose of describing one or more preferred embodiments of the invention and are not intended to limit the invention thereto.

FIG. **1** illustrates an isometric view of an electromagnetic valve according to one embodiment of the present invention. An electromagnetic valve **10** is configured to be attached to a pipe **20** through which water, oil, or other fluids flow through a central channel **22**. The electromagnetic valve **10** connects to the pipe **20** at an interface **12** and includes a stem **14** rising outwardly from the pipe **20**. In one embodiment, the stem **14** extends outwardly from pipe **20** in a direction substantially orthogonal to a central axis of the pipe **20**. A bottom end of the stem **14** is connected to the interface **12** between the pipe **20** and the electromagnetic valve **10** and a top end of the stem **14** is connected to a central housing **16**. A magnetic element housing **18** extends outwardly from at least one side wall of the central housing **16**. In one embodiment, at least one side wall of the magnetic element housing **18** are integrally formed with the at least one side wall of the central housing **16**. In one embodiment, the magnetic element housing **18** extends outwardly from the central housing **16** in a direction substantially orthogonal to a central axis of the stem **14** and substantially orthogonal to the central axis of the pipe **20**. In another embodiment, the magnetic element housing **18** extends outwardly from the central housing **16** in a direction substantially orthogonal to the central axis of the stem **14**, but substantially parallel to the central axis of the pipe **20**. A plurality of wires **30** lead out of the magnetic element housing **18** (in which they are connected to at least one electromagnet) and are connected to a controller (not shown in FIG. **1**) capable of sending electric signals to the electromagnetic valve **10**.

FIG. **2** illustrates an isometric view of an electromagnetic valve with an external section of the valve removed, providing a view of internal components according to one embodiment of the present invention. The magnetic element housing **18** of the electromagnetic valve **10** houses a plurality of permanent magnets surrounding a central shaft **34**, surrounded by a cylindrically sealed container. In one embodiment, the cylindrically sealed container is integral with the central housing **16** of the electromagnetic valve. One or more electromagnets **32** surround the cylindrically sealed container. In one embodiment, the one or more electromagnets **32** include one or more electromagnetic coils wrapped around or positioned adjacent to the exterior cylindrically sealed container.

Upon activation of the one or more electromagnets **32** by an electrical signal travelling through the one or more wires **30** to the one or more electromagnets **32**, the one or more electromagnets **32** create a magnetic force on the plurality of permanent magnets, causing the central shaft **34** to rotate. Importantly, the system rotates the plurality of permanent magnets by altering which of the one or more electromagnets **32** are activated over time (or which segments of the one or more electromagnets **32** are activated over time), such that the magnetic field is rotated. In this way, the system does not require the electromagnets **32** to physically rotate relative to the permanent magnets, unlike prior systems such as that described in U.S. Pat. No. 9,377,121. In one embodiment, at least one portion of the central shaft **34** includes a plurality of teeth or a plurality of ridges **36** configured to matingly engage with a plurality of teeth or a plurality of ridges connected to a second shaft extending through the stem **14**. When the central shaft **34** begins to rotate, the plurality of teeth or plurality of ridges on the central shaft **34** engage with the plurality of teeth or plurality of ridges connected to the second shaft, causing the second shaft to also rotate. The second shaft is connected to a valve element within the pipe **20**, which permits or forbids fluid from flowing through the pipe **20**. Rotation of the second shaft causes the valve element to change positions between an open state and a closed state and therefore activation of the one or more electromagnets **32** causes the valve element to open or close. In one embodiment, the electromagnetic motor is a stator motor, a stepper motor, or the like.

FIG. **4** illustrates an isometric exploded view of an electromagnetic valve according to one embodiment of the present invention. A pipe **20** includes an interface **24** configured to attach to a central shaft **42** rising upwardly from the pipe **20** and a stem housing **44** surrounding the central shaft **42**. In one embodiment, the interface **24** includes a protrusion connected to a valve element within the pipe **20**, wherein rotation of the protrusion causes the valve element to open, allowing fluid through the pipe **20**, or close, preventing the flow of fluid within the pipe **20**. In one embodiment, the bottom of the central shaft **42** includes an opening configured to receive and frictionally engage with the protrusion, such that the protrusion and the central shaft **42** are rotationally coupled. In one embodiment, the stem housing **44** is connected to the interface **24** via one or more bolts, one or more screws, metal welding, and/or any other suitable form of fastener or bonding technique.

The central shaft **42** extends through the stem housing **44** into the central housing **40**. The top of the central housing **40** is sealed by a lid **48**. In one embodiment, the lid **48** is attached to the central housing **40** via one or more bolts, one or more screws, welding, and/or any other suitable form of fastener or bonding technique. In one embodiment, the central shaft **42** is configured to frictionally engage a central bore of a gear engagement element **46**, rotationally coupling the central shaft **42** to the gear engagement element **46**. A plurality of gear teeth or ridges extend outwardly from a side wall of the gear engagement element **46**. In another embodiment, gear teeth or ridges extend directly from a side wall of the central shaft **42** and no separate gear engagement element **46** is used.

The central housing **40** includes a side port **45** through which a side shaft **50** extends. In one embodiment, the side shaft **50** is frictionally engaged with a central bore of a second gear engagement element **52**. A plurality of gear teeth or ridges extend outwardly from a side wall of the second gear engagement element **52**. In another embodiment, gear teeth or ridges extend directly from a side wall of the side shaft **50** and no separate second gear engagement element **52** is used. The gear teeth or ridges of the side shaft **50** are configured to engage with the gear teeth or ridges of the central shaft **42**, such that rotation of the side shaft **50** causes rotation of the central shaft **42**. An end of the side shaft **50** opposite the end including the plurality of gear teeth or ridges is surrounding by a plurality of permanent magnets. This end of the side shaft **50** and the plurality of permanent magnets are nested within a sealed cylindrical compartment **54**. In one embodiment, the sealed cylindrical compartment **54** includes a single opening, configured to receive the end of the side shift **50**. At least a section of the sealed cylindrical compartment **54** is configured to matingly fit within the side port **45** of the central housing **40**. In one embodiment, the outer wall of the section of the sealed cylindrical compartment **54** frictionally engages with the inner wall of the side port **45** of the central housing **40**. In one embodiment, a seal (e.g., an O-ring) is fitted between the sealed cylindrical compartment **54** and the inner wall of the side port **45**. However, importantly, even if there is leakage between the central housing **40** and the sealed cylindrical compartment **54**, there is no potential fluid path outside of the sealed cylindrical compartment **54** and the central housing **40**.

At least one electromagnet surrounds the sealed cylindrical compartment **54** and both the at least one electromagnet and the sealed cylindrical compartment **54** are nested within a magnetic housing **58**. In one embodiment, the magnetic housing **58** is a substantially hollow, cylindrical component including a single opening configured to receive the at least one electromagnet and the sealed cylindrical compartment **54**. In one embodiment, the magnetic housing **58** is configured to tightly attach to a rim surrounding the side port **45** of the central housing **40**. In one embodiment, the magnetic housing **58** is attached to the rim surrounding the side port **45** by at least one bolt, at least one screw, welding, and/or any other suitable form of fastener or permanent bonding technique. In another embodiment, the magnetic housing **58** includes a plurality of protrusions extending longitudinally outwardly in a rim surrounding the opening of the magnetic housing **58**. In yet another embodiment, the system does not include a magnetic housing **58**, but rather the electromagnetic coils are directly attached to the exterior of the sealed cylindrical component **54**, but are not themselves enclosed. This embodiment is not possible in prior art systems, such as in U.S. Pat. No. 9,377,121, as the '121 patent requires the magnetic housing to attach to permanent magnets, whose rotation causes rotation of the magnetic field that actuates the valve. Thus, the magnetic housing in prior art systems is required to actually actuate the valve.

The plurality of protrusions are configured to matingly fit within a plurality of openings in the rim surrounding the side port **45** and frictionally engage with the plurality of openings. A plurality of wires **30** are connected to the electromagnets within the magnetic housing **58** so as to be able to deliver electric signals to individual electromagnets, such that the magnetic field is able to be rotated to actuate the valve.

In one embodiment, the magnetic housing **58** is formed from stainless steel, fiber-reinforced plastic, or another non-magnetic (e.g., diamagnetic) material suitable for use as a pressure vessel. In one embodiment, other components of the electromagnetic valve, such as the central housing **40**, the sealed cylindrical compartment **54**, the stem housing **44**, and/or the central shaft **42**, are also formed from non-magnetic materials. Utilizing non-magnetic materials is used in ensuring that the at least one electromagnet does not face interference in the process of applying a magnetic force to the plurality of permanent magnets, thereby increasing efficiency and reliability of the valve.

FIG. **5** illustrates a top sectional view of an electromagnetic valve according to one embodiment of the present invention. A controller **70** with lead wires **30** is attached to a magnetic actuator for a valve. The magnetic actuator includes one or more permanent magnets **62** surrounding and attached to a rotatable shaft **60**. In one embodiment, the one or more permanent magnets **62** include a plurality of individual permanent magnets **62** circumferentially spaced out and attached around the rotatable shaft **60**. In another embodiment, the one or more permanent magnets **62** includes a single ring magnet surrounding the full circumference of the rotatable shaft **60** and having alternating poles circumferentially around the rotatable shaft **60**. In another embodiment, the one or more permanent magnets **62** includes at least one magnetic array circumferentially surrounding a portion of the rotatable shaft **60**. The rotatable shaft **60** and the one or more permanent magnets **62** are sealed within an enclosed cylindrical compartment **63**. The enclosed cylindrical compartment **63** is surrounding by one or more electromagnets **64**. In one embodiment, the system includes a plurality of electromagnets spaced out around the exterior of the enclosed cylindrical compartment **63**, with each of the plurality of electromagnets **64** able to be individually activated by the controller **70** through the lead wires **30**. In another embodiment, the system includes one or more electromagnets **64** wrapped around the exterior of the enclosed cylindrical compartment **63**, where individual segments of each of the one or more electromagnets **64** are selectively able to be activated. Preferably, the one or more electromagnets **64** or segments of the one or more electromagnets **64** are able to be sequentially, circumferentially activated, allowing the magnetic field generated by the electromagnets **64** to rotate (without physical rotation of the one or more electromagnets **64**) and induce a rotational force on the plurality of permanent magnets **62**, thereby causing the rotatable shaft **60** to rotate.

Optionally, the one or more electromagnets **64** are surrounded by an external cylindrical compartment **66**. In one embodiment, the one or more electromagnets **64** are attached to an interior surface of the external cylindrical compartment **66**. In another embodiment, the one or more electromagnets **64** are attached to an exterior surface of the enclosed cylindrical compartment **63**. In yet another embodiment, the one or more electromagnets **64** are not attached to either the interior surface of the external cylindrical compartment **66**, nor the exterior surface of the enclosed cylindrical compartment **63**, but fitted and held by the fit between the enclosed cylindrical compartment **63** and the external cylindrical compartment **66**.

FIG. **6** illustrates a side sectional view of an electromagnetic valve including a worm drive according to one embodiment of the present invention. The electromagnetic valve **100** includes a ball component **102** including a central passage positioning within a pipe **104**. When the ball component **102** is in an open position, the central passage of the ball component **102** is aligned with the direction of flow within the pipe **104**, allowing fluid to freely flow through the ball component **102**. However, when the ball component **102** is turned by approximately 90°, then side walls of the ball component **102** block the flow of fluid through the pipe **104**. The ball component **102** is connected to a first shaft **106** and coupled with the first shaft **106**, such that rotation of the first shaft **106** causes rotation of the ball component **102**. One of ordinary skill in the art will understand that, in one embodiment, the valve does not necessarily exist in only a purely open or a purely closed position, and is also able to exist in one or more different semi-open states between a fully open state and a fully closed state. For example, in one or more different semi-open states, the ball component is not oriented at 90 degrees nor 0 degrees relative to the pipe flow, but rather at an angle between 0 and 90. Therefore, the state of the valve is able to be continuous, rather than discrete.

The top of the first shaft **106** is connected and coupled with a first gear **107** such that rotation of the first gear **107** causes rotation of the first shaft **106**. Teeth of the first gear **107** are intermeshed with teeth of a worm gear **108**. The worm gear **108**, in turn, is connected with and rotationally coupled with a second shaft **109** such that rotation of the second shaft **109** causes rotation of the worm gear **108**. In this embodiment, the long axis of the second shaft **109** is substantially orthogonal to the long axis of the first shaft **106**. Therefore, as the second shaft **109** rotates, the worm gear **108** rotates. Rotation of the worm gear **108** causes the first gear **107** to rotate in an orthogonal plane due to the intermeshed teeth of the gears. Rotation of the first gear **107** then causes the first shaft **106** to rotate, thereby rotating the ball component **102** and causing the valve mechanism to open or close. An end of the second shaft **109** opposite the worm gear **108** is attached to one or more permanent magnets **110** surrounding the circumference of a section of the second shaft **109**.

Each of the first shaft **106**, the first gear **107**, the worm gear **108**, the second shaft **109**, and the one or more permanent magnets **110** are contained within the valve housing **120**. The valve housing **120** is attached directly to a base plate **103** of the pipe **104** via nuts and bolts, screws, adhesive, welding, latches, and/or any other conventional means of attachment.

A section of the valve housing **120** surrounding the second shaft **109** and, more specifically, the one or more permanent magnets **110** (i.e., a magnetic containment chamber of the valve housing **120**) is surrounded by a magnetic housing **122** including at least one electromagnet **112**. The at least one electromagnet **112** is connected to at least one wire **130** to a controller **132** operable to activate or deactivate the at least one electromagnet **112**. Activation of the at least one electromagnet **112** causes current to move through the at least one electromagnet **112** in a manner that radially shifts the magnetic pole across a portion of or the entire circumference of the magnetic housing **122**. This shifting magnetic pole generates a magnetic force acting upon the one or more permanent magnets **110**, inducing the one or more permanent magnets **110** to move, thereby causing the second shaft

109 to rotate. Importantly, this allows the system to rotate the second shaft and therefore actuate the valve without any parts rotating or moving outside of the pressure vessel of the valve housing 120, thereby reducing the chance of a spark.

In one embodiment, the magnetic containment chamber of the valve housing 120 is formed from at least one substantially non-ferromagnetic material (e.g., stainless steel, thermoplastic materials, titanium, etc.). Utilizing a non-ferromagnetic material between the outer electromagnet 112 and the inner permanent magnets 110 helps strengthen the magnetic connection between the two components and allows for greater torque to be applied. Preferably the valve housing 120 is hermetically sealed and is part of the pressure vessel for the valve, such fluid in the pipe is able to flow into the interior of the valve housing 120 without causing a leak.

FIG. 7 illustrates a side sectional view of an electromagnetic valve including a parallel shaft gear mechanism and a quarter-turn valve according to one embodiment of the present invention. The electromagnetic valve 200 includes a ball component 202 including a central passage positioning within a pipe 204. When the ball component 202 is in an open position, the central passage of the ball component 202 is aligned with the direction of flow within the pipe 204, allowing fluid to freely flow through the ball component 202. However, when the ball component 202 is turned by approximately 90°, then side walls of the ball component 202 block the flow of fluid through the pipe 204. The ball component 202 is connected to a first shaft 206 and coupled with the first shaft 206, such that rotation of the first shaft 206 causes rotation of the ball component 202.

The top of the first shaft 206 is connected and coupled with a first gear 207 such that rotation of the first gear 207 causes rotation of the first shaft 206. Teeth of the first gear 207 are intermeshed with teeth of a second gear 208. The second gear 208, in turn, is connected with and rotationally coupled with a second shaft 209 such that rotation of the second shaft 209 causes rotation of the second gear 208. In this embodiment, the long axis of the second shaft 209 is substantially parallel to the long axis of the first shaft 206. Therefore, as the second shaft 209 rotates, the second gear 208 rotates. Rotation of the second gear 208 causes the first gear 207 to rotate in the same direction due to the intermeshed teeth of the gears. Rotation of the first gear 207 then causes the first shaft 206 to rotate, thereby rotating the ball component 202 and causing the valve mechanism to open or close. An end of the second shaft 209 opposite the second gear 208 is attached to one or more permanent magnets 210 surrounding the circumference of a section of the second shaft 209.

Each of the first shaft 206, the first gear 207, the second gear 208, the second shaft 209, and the one or more permanent magnets 210 are contained within the valve housing 220. The valve housing 220 is attached directly to a base plate 203 of the pipe 204 via nuts and bolts, screws, adhesive, welding, latches, and/or any other conventional means of attachment.

A section of the valve housing 220 surrounding the second shaft 209 and, more specifically, the one or more permanent magnets 210 is surrounded by a magnetic housing 222 including at least one electromagnet 212. The at least one electromagnet 212 is connected to at least one wire 230 to a controller 232 operable to activate or deactivate the at least one electromagnet 212. Activation of the at least one electromagnet 212 causes current to move through the at least one electromagnet 212 in a manner that radially shifts the magnetic pole across a portion of or the entire circumference of the magnetic housing 222. This shifting magnetic pole generates a magnetic force acting upon the one or more permanent magnets 210, inducing the one or more permanent magnets 210 to move, thereby causing the second shaft 209 to rotate. Importantly, this allows the system to rotate the second shaft and therefore actuate the valve without any parts rotating or moving outside of the pressure vessel of the valve housing 220, thereby reducing the chance of a spark.

One of ordinary skill in the art will understand that FIGS. 6-7 are meant to be illustrative of types of valve systems wherein the electromagnetic actuator of the present invention is able to utilized. Other valve component combinations are also able to be used. For example, the electromagnetic actuator is operable to be used in a system with a planetary gear mechanism, such as is described in U.S. Pat. No. 8,496,228.

FIGS. 8-9 illustrate an electromagnetic valve according to one embodiment of the present invention. A pipe 402 carrying fluid includes at least one top plate 404 extending outwardly from the pipe 402. The at least one top plate 404 is attached to a base plate 406 of an electromagnetic valve mechanism. In one embodiment, the at least one top plate 404 and the base plate 406 are attached via nuts and bolts, but one of ordinary skill in the art will understand that the plates are able to be attached by any conventional means, including but not limited to screws, adhesive, and/or welding. The electromagnetic valve mechanism includes a magnetic housing 408 including one or more electromagnets configured to activate the electromagnetic valve mechanism, thereby opening or closing the valve 400.

FIG. 10 illustrates a perspective sectional view of an electromagnetic valve according to one embodiment of the present invention. In one embodiment, the magnetic housing 408 is a hollow cylinder (or otherwise shaped) open to one side that circumferentially surrounds a stem encasement chamber 424. The magnetic housing 408 includes at least one electromagnet 414 positioned between an inner wall of the magnetic housing 408 and an outer wall of the stem encasement chamber 424. The at least one electromagnet 414 is directly attached (e.g., via adhesive, screws, bolts, welding, etc.) to the inner wall of the magnetic housing 408 and/or is directly attached to the outer wall of the stem encasement chamber 424 (e.g., via adhesive, screws, bolts, welding, etc.). In another embodiment, the electromagnet 414 is held in place through contact with both the magnetic housing 408 and the stem encasement chamber 424. In one embodiment, the magnetic housing 408 is not used and the at least one electromagnet 414 is exposed and attached to the stem encasement chamber 424. In one embodiment, a magnetic carrier attached to one or more permanent magnets 412 surrounds a section of a stem 410 within the stem encasement chamber 424. The magnetic carrier is in tight frictional engagement with the stem 410, such that the two components are rotationally coupled (i.e., rotation of the magnetic carrier directly causes rotation of the stem 410).

The stem 410 is attached to a ball 416 (or otherwise shaped component) with a central opening 418 extending through the ball in a single direction. In a closed state, the opening 418 in the ball 416 does not align with the lumen of the pipe 402, while, in an open state, the opening 418 in the ball 416 aligns with the lumen of the pipe 402, allowing fluid to flow. The stem 410 and the ball 416 are rotationally coupled such that rotation of the stem 410 causes rotation of the ball 416. Therefore, rotation of the stem 410 causes the valve 400 to move between an open state and a closed state.

FIGS. 11-12 illustrate exploded views of an electromagnetic valve according to one embodiment of the present invention. A pipe 402 includes a top plate 404 with a stem

410 of a valve mechanism extending through the top plate 404. A stem encasement chamber 424 includes a cylindrical section attached to a base plate 406. In one embodiment, the base plate 407 is configured to attach to the top plate 404 via a plurality of bolts and/or screws, and/or via adhesive and/or welding. In one embodiment, the magnetic housing 408 also includes a cylindrical section attached to a base plate 426. The cylindrical section of the magnetic housing 408 is configured to surround the cylindrical section of the stem encasement chamber 424, while the base plate 426 of the magnetic housing 408 lies on top of the base plate 406 of the stem encasement chamber 424. In one embodiment, the base plate 426 of the magnetic housing 408 includes one or more openings configured to align with one or more openings in the base plate 406 of the stem encasement chamber 424 and one or more openings in the top plate 404 to receive bolts 428 and/or screws and to thereby attached and seal all three components.

Within the stem encasement chamber 424, a section of the stem 410 is surrounded by and frictionally engaged with at least one magnetic carrier 420. In one embodiment, the at least one magnetic carrier 420 is attached to a plurality of permanent magnets 412, such that magnetic force applied to the plurality of permanent magnets 412 causes the at least one magnetic carrier 420 to turn, thereby causing the stem 410 to turn and open or close the valve. In one embodiment, the at least one magnetic carrier 420 includes a plurality of teeth extending outwardly from a side wall of the at least one magnetic carrier 420. In this embodiment, the permanent magnets 412 are wedge shaped components configured to fit between each of the teeth of the at least one magnetic carrier 420 such that the at least one magnetic carrier 420 and the permanent magnets 412 are substantially cylindrical in shape. In one embodiment, a washer 422 fits around the stem 410 and lies on top of the at least one magnetic carrier 420.

In one embodiment, as shown in FIGS. 11 and 12, the magnetic carrier 420 is shaped as a gear, with a plurality of teeth and indents between the teeth, wherein the permanent magnets 412 are fit and attached. In one embodiment, the indents between the teeth are substantially triangular in shape and the permanent magnets 412 are shaped as triangular prisms or a prism having the cross-section of a circular sector.

FIG. 13A illustrates a perspective view of a magnetic carrier according to one embodiment of the present invention. In one embodiment, the actuator stem 450 is surrounded by a magnetic carrier 452. In one embodiment, the magnetic carrier 452 is formed from epoxy, or any other suitable polymer material. In one embodiment, the plurality of magnets 454 are embedded into one or more indents in the magnetic carrier 452. In one embodiment, the indents are partially rectangular in shape, as shown in FIG. 13A. The magnetic carrier 452 therefore unifies the magnets into an array tightly surrounding the actuator stem 450.

FIG. 13B illustrates a perspective view of an actuator stem collar with permanent magnets directed attached to it according to one embodiment of the present invention. In one embodiment, rather than attaching the permanent magnets to the magnetic carrier via an epoxy with specified indentations, the permanent magnets 462 are directly attached to the actuator stem collar 460. In one embodiment, rather than having a circular cross section, the actuator stem collar 460 includes a polygonal cross-section, such as the octagonal cross-section shown in FIG. 13B. However, one of ordinary skill in the art will understand that the present invention is not limited to actuator stem collars 460 having octagonal cross-sections, but is able to have any number of sides equal to the number of magnets 462 included in the application. Alternatively, in one embodiment, the permanent magnets are directed attached to the actuator stem itself.

FIGS. 14 and 15 illustrate side sectional and exploded views of an electromagnetic quarter-turn valve utilizing a planetary gear mechanism. A valve mechanism 500 according to one embodiment of the present invention includes a quarter turn valve element 502 positioned the lumen of a pipe 530 or other fluid carrying conduit. The quarter turn valve element 502 includes a central passage extending through from a front side to a rear side of the valve element 502. The alignment of this passage with the lumen of the pipe 530 determines whether the valve is open. Closed, or semi-open, as it is capable of entirely allowing flow, entirely blocking flow through the pipe 530, or partially blocking the pipe 530.

The quarter turn valve element 502 is connected to and rotationally coupled with a valve stem 504 rising upwardly from the pipe 530. A center gear 506, also called a sun gear, is attached to a top of the valve stem 504. The valve mechanism 500 further includes an actuator stem 508, the bottom of which is attached to a moveable carrier 510, including a plurality of prongs. The bottom of each of the prongs is connected to a planet gear 512, configured to intermesh with the central gear 506 of the valve stem 504, such that rotation of the actuator stem 508 causes rotation of the valve stem 504 (and therefore the valve element 502) due to the intermesh of the center gear 506 and the planet gears 512 as a planetary gear mechanism. In one embodiment, the actuator stem 508 and the valve stem 504 are substantially parallel and/or collinear.

The actuator stem 508, the center gear 506, the planet gears 512 and at least a portion of the valve stem 504 are surrounded by a valve housing 516, defining an outer pressure vessel of the valve. A ring gear 526 lines an interior surface of the valve housing 516, facilitating the movement of the planet gears 512 around the central gear 506. The valve housing 516 is attached to a valve bonnet 522 surrounding a portion of the valve stem 504 via one or more bolts, screws, adhesive, welding, and/or any other connection mechanism configured to provide an airtight seal for the valve housing 516 so as to define the pressure vessel. In one embodiment, at least one sealing element 524 is positioned between the valve housing 516 and the valve bonnet 522.

One of more magnetic elements, preferably permanent magnets 514, surround and are connected to the actuator stem 508 within the valve housing 516. Torque applied to the permanent magnets 514, therefore, is able to rotate the actuator stem 508 and therefore actuate the valve element 502 to move between open, semi-open, and closed positions. One or more electromagnets 518 surround a section of the valve housing 516 proximate to the permanent magnets 514. The electromagnets 518 are able to include electromagnetic bar magnets and/or one or more coils surrounding the valve housing 516. These electromagnets 518 are able to be activated by one or more energy sources and then able to apply torque to the permanent magnets 514 via physical rotation of the electromagnets 518 or, more preferably, via rotation of the produced magnetic field by varying the amount of magnetic field generated by each of the electromagnets 518 (or sections of the electromagnets) over time without physical rotation. In one embodiment, the electromagnets 518 are surrounded by an exterior casing 520.

In one embodiment, the plurality of inner permanent magnets is encased with in an interior isolation chamber formed from a non-ferrous, non-ferromagnetic material. This interior isolation chamber is useful, as it prevents materials carried through the pipe (e.g., oil, gas, hydrogen, etc.) from as easily contacting the permanent magnets in the event that it infiltrates the valve housing as part of the pressure vessel. This is especially useful for oil and gas applications where prolonged exposure to oil and gas often affects the efficacy of the magnets. Such an interior isolation chamber is a feature only considered for such valves that both have interior magnets and also have the valve housing serve as part of the pressure vessel, therefore solving a unique issue unaddressed in the prior art. In one embodiment, the valve of the present invention is used in nuclear applications.

FIG. **16** is a schematic diagram of an embodiment of the invention illustrating a computer system, generally described as **800**, having a network **810**, a plurality of computing devices **820**, **830**, **840**, a server **850**, and a database **870**.

The server **850** is constructed, configured, and coupled to enable communication over a network **810** with a plurality of computing devices **820**, **830**, **840**. The server **850** includes a processing unit **851** with an operating system **852**. The operating system **852** enables the server **850** to communicate through network **810** with the remote, distributed user devices. Database **870** is operable to house an operating system **872**, memory **874**, and programs **876**.

In one embodiment of the invention, the system **800** includes a network **810** for distributed communication via a wireless communication antenna **812** and processing by at least one mobile communication computing device **830**. Alternatively, wireless and wired communication and connectivity between devices and components described herein include wireless network communication such as WI-FI, WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS (WIMAX), Radio Frequency (RF) communication including RF identification (RFID), NEAR FIELD COMMUNICATION (NFC), BLUETOOTH including BLUETOOTH LOW ENERGY (BLE), ZIGBEE, Infrared (IR) communication, cellular communication, satellite communication, Universal Serial Bus (USB), Ethernet communications, communication via fiber-optic cables, coaxial cables, twisted pair cables, and/or any other type of wireless or wired communication. In another embodiment of the invention, the system **800** is a virtualized computing system capable of executing any or all aspects of software and/or application components presented herein on the computing devices **820**, **830**, **840**. In certain aspects, the computer system **800** is operable to be implemented using hardware or a combination of software and hardware, either in a dedicated computing device, or integrated into another entity, or distributed across multiple entities or computing devices.

By way of example, and not limitation, the computing devices **820**, **830**, **840** are intended to represent various forms of electronic devices including at least a processor and a memory, such as a server, blade server, mainframe, mobile phone, personal digital assistant (PDA), smartphone, desktop computer, netbook computer, tablet computer, workstation, laptop, and other similar computing devices. The components shown here, their connections and relationships, and their functions, are meant to be exemplary only, and are not meant to limit implementations of the invention described and/or claimed in the present application.

In one embodiment, the computing device **820** includes components such as a processor **860**, a system memory **862** having a random access memory (RAM) **864** and a read-only memory (ROM) **866**, and a system bus **868** that couples the memory **862** to the processor **860**. In another embodiment, the computing device **830** is operable to additionally include components such as a storage device **890** for storing the operating system **892** and one or more application programs **894**, a network interface unit **896**, and/or an input/output controller **898**. Each of the components is operable to be coupled to each other through at least one bus **868**. The input/output controller **898** is operable to receive and process input from, or provide output to, a number of other devices **899**, including, but not limited to, alphanumeric input devices, mice, electronic styluses, display units, touch screens, gaming controllers, joy sticks, touch pads, signal generation devices (e.g., speakers), augmented reality/virtual reality (AR/VR) devices (e.g., AR/VR headsets), or printers.

By way of example, and not limitation, the processor **860** is operable to be a general-purpose microprocessor (e.g., a central processing unit (CPU)), a graphics processing unit (GPU), a microcontroller, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), a Programmable Logic Device (PLD), a controller, a state machine, gated or transistor logic, discrete hardware components, or any other suitable entity or combinations thereof that can perform calculations, process instructions for execution, and/or other manipulations of information.

In another implementation, shown as **840** in FIG. **16**, multiple processors **860** and/or multiple buses **868** are operable to be used, as appropriate, along with multiple memories **862** of multiple types (e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core).

Also, multiple computing devices are operable to be connected, with each device providing portions of the necessary operations (e.g., a server bank, a group of blade servers, or a multi-processor system). Alternatively, some steps or methods are operable to be performed by circuitry that is specific to a given function.

According to various embodiments, the computer system **800** is operable to operate in a networked environment using logical connections to local and/or remote computing devices **820**, **830**, **840** through a network **810**. A computing device **830** is operable to connect to a network **810** through a network interface unit **896** connected to a bus **868**. Computing devices are operable to communicate communication media through wired networks, direct-wired connections or wirelessly, such as acoustic, RF, or infrared, through an antenna **897** in communication with the network antenna **812** and the network interface unit **896**, which are operable to include digital signal processing circuitry when necessary. The network interface unit **896** is operable to provide for communications under various modes or protocols.

In one or more exemplary aspects, the instructions are operable to be implemented in hardware, software, firmware, or any combinations thereof. A computer readable medium is operable to provide volatile or non-volatile storage for one or more sets of instructions, such as operating systems, data structures, program modules, applications, or other data embodying any one or more of the methodologies or functions described herein. The computer readable medium is operable to include the memory **862**, the processor **860**, and/or the storage media **890** and is operable be a single medium or multiple media (e.g., a centralized or distributed computer system) that store the one or more sets of instructions **900**. Non-transitory computer readable media includes all computer readable media, with the sole exception being a transitory, propagating signal per se. The instructions **900** are further operable to be transmitted or received over the network **810** via the network interface unit **896** as communication media, which is operable to include a modulated data signal such as a carrier wave or other transport mechanism and includes any delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics changed or set in a manner as to encode information in the signal.

Storage devices **890** and memory **862** include, but are not limited to, volatile and non-volatile media such as cache, RAM, ROM, EPROM, EEPROM, FLASH memory, or other solid state memory technology; discs (e.g., digital versatile discs (DVD), HD-DVD, BLU-RAY, compact disc (CD), or CD-ROM) or other optical storage; magnetic cassettes, magnetic tape, magnetic disk storage, floppy disks, or other magnetic storage devices; or any other medium that can be used to store the computer readable instructions and which can be accessed by the computer system **800**.

In one embodiment, the computer system **800** is within a cloud-based network. In one embodiment, the server **850** is a designated physical server for distributed computing devices **820**, **830**, and **840**. In one embodiment, the server **850** is a cloud-based server platform. In one embodiment, the cloud-based server platform hosts serverless functions for distributed computing devices **820**, **830**, and **840**.

In another embodiment, the computer system **800** is within an edge computing network. The server **850** is an edge server, and the database **870** is an edge database. The edge server **850** and the edge database **870** are part of an edge computing platform. In one embodiment, the edge server **850** and the edge database **870** are designated to distributed computing devices **820**, **830**, and **840**. In one embodiment, the edge server **850** and the edge database **870** are not designated for distributed computing devices **820**, **830**, and **840**. The distributed computing devices **820**, **830**, and **840** connect to an edge server in the edge computing network based on proximity, availability, latency, bandwidth, and/or other factors.

It is also contemplated that the computer system **800** is operable to not include all of the components shown in FIG. **16**, is operable to include other components that are not explicitly shown in FIG. **16**, or is operable to utilize an architecture completely different than that shown in FIG. **16**. The various illustrative logical blocks, modules, elements, circuits, and algorithms described in connection with the embodiments disclosed herein are operable to be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application (e.g., arranged in a different order or partitioned in a different way), but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

Certain modifications and improvements will occur to those skilled in the art upon a reading of the foregoing description. The above-mentioned examples are provided to serve the purpose of clarifying the aspects of the invention and it will be apparent to one skilled in the art that they do not serve to limit the scope of the invention. All modifications and improvements have been deleted herein for the sake of conciseness and readability but are properly within the scope of the present invention.

The invention claimed is:

1. An electromagnetically actuated valve system, comprising:

at least one valve blocking mechanism positioned within a pipe, wherein, in an open position, the at least one valve blocking mechanism substantially allows fluid flow through the pipe, and wherein, in a closed position, the at least one valve blocking mechanism substantially prohibits fluid through the pipe;

a valve stem mechanically coupled with the at least one valve blocking mechanism, such that rotation of the valve stem causes the at least one valve blocking mechanism to change between the open position, the closed position, and one or more semi-open positions between the open position and the closed position;

a center gear attached to a stop of the valve stem;

an actuator stem, connected to a plurality of planet gears, configured to intermesh with the center gear of the valve stem;

one or more permanent magnets embedded in indentations on an exterior of a magnetic carrier surrounding a section of the actuator stem, wherein the indentations have a rectangular profile;

a valve housing sealingly enclosing the at least one valve blocking mechanism, the valve stem, the actuator stem, the center gear, the plurality of planet gears, and the one or more permanent magnets, wherein the valve housing includes at least one magnetic containment chamber surrounding the one or more permanent magnets;

at least one electromagnet connected to an external surface of the at least one magnetic containment chamber; and

a controller electrically connected to the at least one electromagnet;

wherein the actuator stem includes an upper cylindrical portion connected with a lower base, with a plurality of prongs extending downwardly from the lower base;

wherein the magnetic carrier surrounds the upper cylindrical portion of the actuator stem, and wherein the plurality of planet gears are directly connected with the plurality of prongs;

wherein the controller alternates the at least one valve blocking mechanism between the open position, the closed position, and the one or more semi-open positions by activating the at least one electromagnet; and

wherein the magnetic containment chamber is formed from at least one substantially non-ferromagnetic material.

2. The system of claim **1**, wherein the actuator stem and the valve stem are substantially parallel and collinear.

3. The system of claim **1**, wherein the at least one valve blocking mechanism is a quarter turn valve mechanism.

4. The system of claim **1**, wherein the at least one electromagnet includes a plurality of electromagnets, and wherein the controller alternates the at least one valve blocking mechanism between the open position and the closed position by sequentially activating one or more of the plurality of electromagnets.

5. The system of claim **1**, wherein a ring gear configured to intermesh with the plurality of planet gears extends inwardly from an interior surface of the valve housing.

6. The system of claim **1**, wherein the magnetic containment chamber is formed from stainless steel, titanium, and/or a thermoplastic material.

7. The system of claim **1**, wherein an outer magnetic housing surrounds the at least one electromagnet.

8. The system of claim **1**, wherein the at least one electromagnet does not physically rotate relative to the at least one magnetic containment chamber during actuation of the system.

9. An electromagnetically actuated valve system, comprising:

at least one valve blocking mechanism positioned within a pipe, wherein, in an open position, the at least one valve blocking mechanism substantially allows fluid flow through the pipe, and wherein, in a closed position, the at least one valve blocking mechanism substantially prohibits fluid through the pipe;

a valve stem mechanically coupled with the at least one valve blocking mechanism, such that rotation of the valve stem causes the at least one valve blocking mechanism to change between the open position, the closed position, and one or more semi-open positions between the open position and the closed position;

a center gear attached to a stop of the valve stem;

an actuator stem, connected to a plurality of planet gears, configured to intermesh with the center gear of the valve stem;

one or more permanent magnets embedded in indentations on an exterior of a magnetic carrier surrounding a section of the actuator stem, wherein the indentations have a rectangular profile;

a valve housing sealingly enclosing the at least one valve blocking mechanism, the valve stem, the actuator stem, the center gear, the plurality of planet gears, and the one or more permanent magnets, wherein the valve housing includes at least one magnetic containment chamber surrounding the one or more permanent magnets;

at least one electromagnet connected to an external surface of the at least one magnetic containment chamber; and

a controller electrically connected to the at least one electromagnet;

wherein the actuator stem includes an upper cylindrical portion connected with a lower base, with a plurality of prongs extending downwardly from the lower base;

wherein the magnetic carrier surrounds the upper cylindrical portion of the actuator stem, and wherein the plurality of planet gears are directly connected with the plurality of prongs;

wherein the controller alternates the at least one valve blocking mechanism between the open position, the closed position, and the one or more semi-open positions by activating the at least one electromagnet; and

wherein the at least one electromagnet does not physically rotate relative to the at least one magnetic containment chamber during actuation of the system.

10. The system of claim **9**, wherein the actuator stem and the valve stem are substantially parallel and collinear.

11. The system of claim **9**, wherein the at least one valve blocking mechanism is a quarter turn valve mechanism.

12. The system of claim **9**, wherein the at least one electromagnet includes a plurality of electromagnets, and wherein the controller alternates the at least one valve blocking mechanism between the open position, the one or more semi-open positions, and the closed position by sequentially activating the one or more of the plurality of electromagnets.

13. The system of claim **9**, wherein a ring gear configured to intermesh with the plurality of planet gears extends inwardly from an interior surface of the valve housing.

14. The system of claim **9**, wherein the at least one magnetic containment chamber is formed of stainless steel.

15. The system of claim **9**, wherein an outer magnetic housing surrounds the at least one electromagnet.

16. An electromagnetically actuated valve system, comprising:

at least one valve blocking mechanism positioned within a pipe, wherein, in an open position, the at least one valve blocking mechanism substantially allows fluid flow through the pipe, and wherein, in a closed position, the at least one valve blocking mechanism substantially prohibits fluid through the pipe;

a valve stem mechanically coupled with the at least one valve blocking mechanism, such that rotation of the valve stem causes the at least one valve blocking mechanism to change between the open position, the closed position, and one or more semi-open positions between the open position and the closed position;

a center gear attached to a stop of the valve stem;

an actuator stem, connected to a plurality of planet gears, configured to intermesh with the center gear of the valve stem;

one or more permanent magnets embedded in indentations on an exterior of a magnetic carrier surrounding a section of the actuator stem, wherein the indentations have a rectangular profile;

a valve housing sealingly enclosing the at least one valve blocking mechanism, the valve stem, the actuator stem, the center gear, the plurality of planet gears, and the one or more permanent magnets, wherein the valve housing includes at least one magnetic containment chamber surrounding the one or more permanent magnets;

at least one electromagnet connected to an external surface of the at least one magnetic containment chamber; and

a controller electrically connected to the at least one electromagnet;

an outer magnetic housing surrounding the at least one electromagnet;

wherein the actuator stem includes an upper cylindrical portion connected with a lower base, with a plurality of prongs extending downwardly from the lower base;

wherein the magnetic carrier surrounds the upper cylindrical portion of the actuator stem, and wherein the plurality of planet gears are directly connected with the plurality of prongs;

wherein the controller alternates the at least one valve blocking mechanism between the open position, the closed position, and the one or more semi-open positions by activating the at least one electromagnet; and

wherein the actuator stem and the valve stem are substantially parallel and collinear.

17. The system of claim **16**, wherein the magnetic containment chamber is formed from at least one substantially non-ferromagnetic material.

18. The system of claim **16**, wherein the at least one valve blocking mechanism is a quarter turn valve mechanism.

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