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(54) **Titre : SYSTEME DE REFOULEMENT D'ADDITIF DE FLUIDE COMPRENANT UN DEBITMETRE**
(54) **Title: FLUID ADDITIVE DELIVERY SYSTEM WITH FLOW METER**

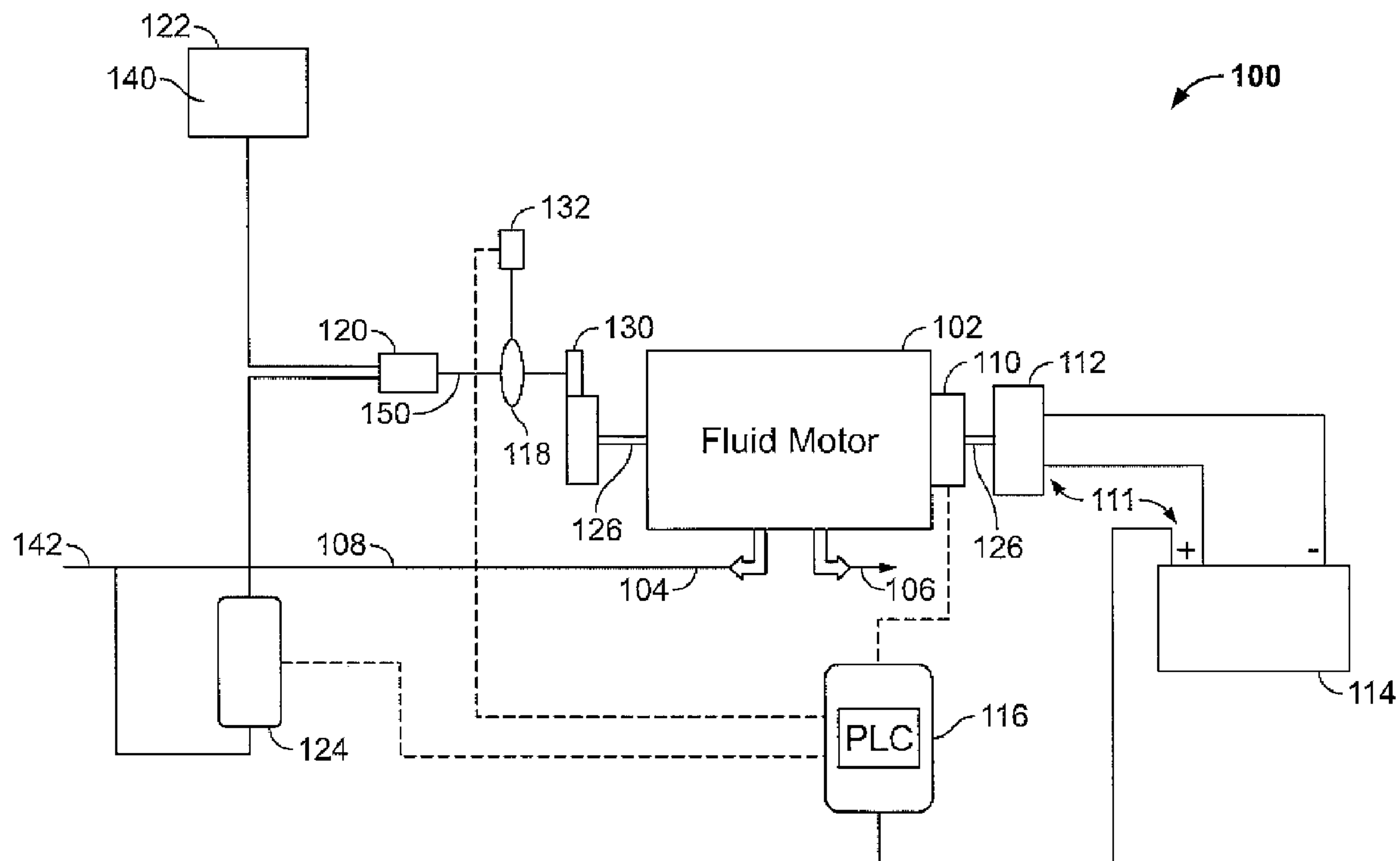


FIG. 1

(57) **Abrégé/Abstract:**

A system for delivering an additive to a flowing fluid wherein the system is in whole or in part powered by the flow of the fluid is provided. The fluid-additive delivery system includes a fluid motor, a speed sensor, an electricity generation and storage system, a clutch, an additive pump, and a flow meter, where the fluid motor and the flow meter are in fluid communication with a piping of the fluid to which the fluid additive is to be added. The flow meter provides high resolution with infinite turndown, providing a flow meter



(57) Abrégé(suite)/Abstract(continued):

which may be used in low flow situations and with fluid additives. The flow rate of an additive fluid is determined in real time with high resolution by providing a novel reciprocating positive-displacement flow meter using magnetically coupled components and a transducer to identify the flow rate of the fluid.

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(57) Abstract: A system for delivering an additive to a flowing fluid wherein the system is in whole or in part powered by the flow of the fluid is provided. The fluid-additive delivery system includes a fluid motor, a speed sensor, an electricity generation and storage system, a clutch, an additive pump, and a flow meter, where the fluid motor and the flow meter are in fluid communication with a piping of the fluid to which the fluid additive is to be added. The flow meter provides high resolution with infinite turndown, providing a flow meter which may be used in low flow situations and with fluid additives. The flow rate of an additive fluid is determined in real time with high resolution by providing a novel reciprocating positive-displacement flow meter using magnetically coupled components and a transducer to identify the flow rate of the fluid.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Fluid additive delivery system with flow meter

FIELD OF THE INVENTION

[0001] The present invention provides a system for delivery of an additive to a flowing
5 fluid. More particularly, the invention relates to a system for delivering an additive to a flowing
fluid wherein the system is in whole or in part powered by the flow of the fluid. The present
invention further provides a system for determining the flow rate of a fluid. The invention may
be used for measuring the rate of fluid flow and may be included in a larger system for
controlling the flow rate of the fluid. The system may include an improved flow meter which
10 includes a ferrous floating internal piston in a reciprocating flow meter, wherein the internal
piston is magnetically tied to a coupling arm with an end in magnetic contact with a linear digital
encoding transducer equivalent in operable length to the full stroke of the ferrous floating
internal piston and which provides immediate data regarding the smallest movement of the
internal piston.

DESCRIPTION OF THE RELATED ART

[0002] Systems for introducing measured fluids into flowing fluids are well known. A
popular means of injecting chemical additives into various liquid streams, particularly fuels, is to
use a signal generated from a flow meter in the recipient line to control an injection pump.
20 Various systems exist to meter the amount of additive(s) injected into a fluid, usually drawing
electrical power from the system associated with the fluid delivery. These systems generally
inject the fluid additive into the flow of the main fluid, causing the fluid additive to stratify and
not blend thoroughly, often precluding the desired outcome or requiring excessive amounts of
fluid additive to obtain the desired benefit. Some additives such as lubricity agents and

conductivity agents that are injected at a very low rate (PPM) can be ineffective if not blended thoroughly.

[0003] Moreover, each additive requires its own reservoir and generally its own pump, particularly where multiple additives may be simultaneously added.

5 [0004] Current systems suffer from a number of shortcomings. Most systems are not self-contained, requiring substantial effort to address any issues within the system or to make changes. Additionally, some systems use error-correcting control systems which, based on data reported to a computer from product and additive meters, open or close a valve attached to a highly pressurized additive supply line (such as 165 psi (1,137.63 kPa)) until the desired volume
10 of additive has been delivered for the product, according to volume of product reported by the main product meter. As a result of the error correction system employed, these systems typically provide an oversupply of additive to ensure minimum delivery, an undesirable and costly approach, as are constantly in a state of correction in search of the calculated ratio.

[0005] Among the systems known in the art which have attempted to address some of
15 these shortcomings are U.S. Patent 5,513,963 issued to Walton for a direct action fluid motor and injection pump, U.S. Patent 6,910,405 issued to Walton, et. al. for an on/off switch for a liquid additive injection pump, and U.S. Patent 7,066,353 issued to Hammonds for a fluid powered additive injection system. However, none of these systems have provided a self-contained system incorporating a fluid motor, speed sensor, electricity generator and battery, a clutch
20 operated additive control pump, a flow meter and a computer controller, particularly one capable of relatively-low pressure operation.

[0006] Systems for measuring fluid flow rates are desirable in devices or systems where flow rates must be controlled or verified. Measurement of flow which is accurate, highly precise

(high resolution), and consistent is important in various systems utilizing fluid flow for operation. Measurement of those flow rates often must be expressed and communicated in an electronic format that is compatible with programmable logic devices. Moreover, it is desirable to have a high turndown in these systems, although typically one of the most substantial
5 problems with existing meters. Existing meters thus have a narrow (often very narrow) range of operations, problematic in cases of fuel injection where flow may operate between zero flow and high flow rates.

[0007] Systems for delivering fluids, including those for introducing fluids as additives into other fluid flows, are well known in the art and are generally desired where the fluid may
10 have a limited duration of effectiveness after introduction to a flowing untreated fluid, particularly in cases where additives may be selected on site based on the specific need at the time. In some of these applications, it is necessary to precisely control the flow of the metered fluid, such as an additive, relative to the flow of a second fluid, such as fuel, being delivered so as to maintain a ratio of fuel to additive, usually represented in parts per million. This can be
15 particularly critical where the flow of the second fluid is relatively low, driving down the flow rate of the metered fluid. Thus, doing so requires accurate measurement of the additive, particularly where usually delivered at a very low flow rate.

[0008] With regard to addition of a treating agent, the efficacy of the treated fluid may be effected if the proper volume of additive is not introduced to the untreated flow of a process
20 stream at the current flow rate. Additionally, the cost of the additive to be introduced may be quite high, so cost-effectiveness requires the flow rate, as measured by a flow meter and potentially communicated to an associated logic controller which may in turn control the pump supplying the additive. Ensuring consistent delivery of additive to the untreated fluid is a

necessity. Introduction of additive at actual flow rates which are above or below the desired flow rate is undesirable, such as in cases where the additive is introduced to an untreated flow of a petroleum-based fluid where combustion may be over- or under-pressurized in the engine, potentially posing a danger to operators and others. Moreover, other additives effect lubricity or conductivity of fuel with each having the need to be injected accurately over a wide (often very wide) range of flow.

[0009] Thus, accuracy, high resolution, and consistency are needed for systems utilizing fluid flow, including systems where additives are used in conjunction with motor and aviation fuels, water-treatment systems, and other systems.

[0010] Among the prior art devices directed to determining the flow rate of a fluid flow, either for determination of flow rates or for addition of a treating agent are positive displacement meters such as oval gear flow meters, which may consist of two close tolerance oval gears which, when fluid is passed between the two, produce a rotary motion within the meter housing. A shaft connected to one of the meter oval gears includes a rotating hall affect sensor that is used to signal the speed of the rotating shaft. A revolution of the shaft represents a certain volume of fluid passing through the meter by virtue of the volumetric displacement between the two gears inside the meter housing. Meters of this type are very sensitive to solids since the tolerances within the meter are very close. Such meters are prone to clogging and locking up as a result of various foreign material found in fluids such as additives or treating agents. In addition, many fluids, additives or treating agents have solids that are a part of the fluid, additive or treating agent itself which tend to be highly abrasive. This abrasiveness quickly wears the meter and causes it to quickly lose efficiency and its ability to accurately reflect the volume passing through the meter. Additives such as dyes are very abrasive with a high solids content making

them inappropriate for use with oval gear meters. Many fuel additives are injected at extremely small ratios as low as 1 PPM. Oval gear meters require minimum flow rates that far exceed those rates found in additive injection, making them inoperable in these applications.

[0011] Other prior art metering systems have included float type flow meters that have utilized floats in static, vertically-aligned flows, and reciprocating pistons which have generally measured flow rate according to travel of the reciprocating piston from one end of the associated cylinder to the other.

[0012] Such metering systems are of limited utility in measuring flow rates. Float systems similarly are of limited benefit where the system is susceptible to being out of vertical alignment.

[0013] Where used for additive delivery in fuels, such metering systems are of limited utility, specifically where the volume of additive introduced is particularly small relative of the untreated fluid (such as less (preferably substantially less) than 0.25% or, non-equivalently less than 2500 parts per million (PPM) (additive to fuel)). Substantially higher ratios approach the concept of blending.

[0014] In addition to the foregoing, due to the minute amount of additive dispensed, and the long time needed for the typical reciprocating metering system to complete one cycle (and hence provide a flow rate) that real time flow rates cannot be obtained the resulting flow rate has not assurance that the resulting average is consistent with the dispensing rate throughout the cycle.

[0015] There is therefore a need for an accurate meter flow which performs without reference to the system's orientation with minimal moving parts. There is also a need for a flow meter with a high turndown, providing a wide range of operation. There is also a need to control

the flow rate of a relatively minute volume of additive to be dispensed into a flow of untreated fluid by providing a high resolution additive delivery system, to monitor the flow rate of a fluid with high resolution, or to maintain at high resolution a desired flow rate of additive.

SUMMARY OF THE INVENTION

5 [0016] It is therefore, a principle object of the present invention to provide a system for delivering an additive to a flowing fluid wherein the system is in whole or in part powered by the flow of the fluid and which provides the additive at lower pressure, preferably only that needed to inject additive fluid into a product flow.

10 [0017] This achieved by providing a fluid motor adapted to receive a fluid from a piping and having an output shaft rotatably driven by the fluid as it moves between the fluid inlet of the fluid motor and its fluid output, a speed sensor adapted to be associated with the output shaft and adapted to provide a signal to a computer indicative of rotational speed of the output shaft, an electricity generation and storage system comprising a direct current generator and an electrical battery, where the direct current generator is adapted to be driven by the fluid motor's output
15 shaft and adapted to provide electricity to the electrical battery, a clutch adapted to be associated with the output shaft and adapted to engage a shaft of an additive pump upon activation by a computer, where the additive pump is adapted to be rotatably driven by the output shaft (upon engagement by the clutch and is in fluid communication with a reservoir of a fluid additive and adapted to pump the fluid additive to a flow meter, where the flow meter has a meter input
20 adapted for fluid communication with the additive pump, a meter output adapted for fluid communication of the fluid additive to the fluid in the piping, and is adapted to provide a signal to the computer indicative of the actual flow rate from the additive pump.

[0018] Alternatively, the system may provide a fluid motor in communication with a

5 piping of fluid where the fluid motor has an output shaft rotatably driven by the fluid moving between the fluid motor's fluid inlet and fluid output, a speed sensor associated with the fluid motor's output shaft and providing a signal to a computer indicative of rotational speed of said output shaft, a direct current generator in mechanical connection with the fluid motor's output
10 shaft and electrically connected to an electrical battery, a clutch associated with the fluid motor's output shaft and engaging a shaft of an additive pump upon activation, where the additive pump is rotatably driven by the fluid motor's output shaft upon engagement by the clutch, where the additive pump is in fluid communication with a reservoir of fluid additive and impels the fluid additive to a flow meter having a meter input in fluid communication with the additive pump,
15 having a meter output in one-way fluid communication with the piping, and which provides a signal to a computer indicative of the actual flow rate from said additive pump.

[0019] It is also a principle object of the present invention to provide a flow meter, particularly a positive displacement reciprocating flow meter, which produces accurate metering with minimal moving parts and which is accurate over time, regardless of pump efficiency or
20 system leakage. This achieved by providing a cylindrical body with fluid connectors at its sealed ends, a ferrous floating internal piston, a cylindrical ring freely encircling the cylindrical body and magnetically coupled to the ferrous floating internal piston, a high resolution linear digital encoding transducer (preferably cylindrical and absolute) preferably parallel to and equivalent in length to the cylindrical body, a coupling arm integrally affixed to the magnetic ring so as to
25 function as a single unit therewith and having a magnetic section contacting the linear digital encoding transducer, with a valve system providing additive to reciprocate the ferrous floating internal piston and to dispense additive to the untreated fluid, and a computer adapted to determine the position of the coupling arm relative to said linear digital encoding transducer to

determine position, and, by measurement of time and determination of change in direction, velocity and a valve controller to control the valve system to reciprocate the ferrous floating internal piston. The sealed ends of the cylindrical body and the magnetic coupling between the ferrous floating internal piston and the linear digital encoding transducer provide reduce or
5 eliminate leakage and maintenance associated with meters since there are no dynamic seals involved.

[0020] The valve system may have a fluid input from the flowing supply of fluid, such an additive, a fluid output, and be in fluid communication with a first end connector at one end of the reciprocating flow meter and in fluid communication with a second end connector at the
10 opposite end of the reciprocating flow meter. The valve system may be switchably operable among a first position and a second position to provide for reciprocation of the ferrous floating internal piston. Switching may be accomplished by a valve driven by solenoids or other actuators. In the first position, the fluid input is in communication with the flowing supply of an additive and the fluid output is in communication with the flow of untreated fluid. Thus the first
15 position connects the fluid input and the second end connector and connects the first end connector with the fluid output and the second position connects the fluid input and the first end connector and connects the second end connector with the fluid output. Thus, the valve system is controlled to cause reciprocation of the ferrous floating internal piston between the cylinder first end and the cylinder second end when the piston approaches each end.

20 [0021] The present flow meter invention, by virtue of its high resolution and infinite turndown, may also be incorporated into a flow control system, such as that for introduction of a flowing additive at a very low ratio of additive fluid to untreated fluid, particularly in cases where a relatively minute volume of additive fluid is to be dispensed into a flow of untreated

fluid. The flow meter invention may be used with a pumped supply of additive to monitor and, in conjunction with control of the pump, control the flow of untreated fluid to provide additive at very low ratios of additive to untreated fluid by volume.

[0022] A flow control system incorporating the flow meter invention to control the flow of liquid, such as an additive fluid, may also include an output computer providing an output signal consistent with each flow rate and an fluid flow controller intermediate the supply of fluid and the valve system which can control the flow of fluid into the system, through various flow rates or at least between flowing and non-flowing positions. The fluid flow controller may be a computer-controlled pump, potentially operable among a plurality of pump speeds (which may not need to be quantified) or may be a valve in conjunction with a supply of fluid under pressure.

[0023] In operation, the flow control system may be employed to ensure the appropriate flow rate (such as the ultralow ratios referenced above), regardless of the efficiency or accuracy of the associated additive pump. This may be accomplished by the flow control system receiving a user input for a desired flow rate of additive, which then activates an additive flow controller at an actual flow rate presumed consistent with the desired flow rate of additive. However, as pumps are prone to wear and leakage, resulting in inaccuracies, the method must verify and adjust, as necessary, the actual flow rate. This is accomplished by introducing the presumed flow rate from the pump to a positive displacement reciprocating piston flow meter for verification.

[0024] The flow control system can then compare the presumed flow rate to the output signal to identify the deviation from desired flow rate. Based on determination of this deviation, the flow control system can then adjust the pump's actual flow rate at the flow controller to obtain the desired flow rate.

[0025] Unlike the prior art, the present flow meter invention provides a high degree of

accuracy by providing identification of the position of the piston in the reciprocating flow meter at all points between the ends of the flow meter. This particularly important as it provides an instantaneous, or real time, rate of flow. Thus, the lag time associated with the imprecision of measurements based on the total stroke of the piston through the flow meter is avoided. Delays
5 in time of position data create a corresponding delay in the adjustments necessary to maintain the pre-set ratio. This lag time had historically been a problem in fuel additive delivery systems when the ratio of additive to untreated fluid was less than 1%. In operation, this results in an additive concentration of about 2500 PPM. In the fuel additive industry, anything over 2500 PPM or ¼% is considered blending and may be accomplished with the lower resolution flow
10 meters or a rotary positive displacement device.

[0026] The foregoing and other objectives, features and advantages of the invention will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

15 [0027] So that the manner in which the described features, advantages and objects of the invention, as well as others which will become apparent, are attained and can be understood in detail, more particular description of the invention briefly summarized above may be had by reference to the embodiments thereof that are illustrated in the drawings, which drawings form a part of this specification. It is to be noted, however, that the appended drawings illustrate only a
20 typical preferred embodiment of the invention and are therefore not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

[0028] FIG. 1 illustrates the system for delivery of an additive.

[0029] FIG. 2 illustrates a flow meter which may be used in the system for delivery of an

additive.

[0030] FIG. 3 illustrates the cylinder portion of the flow meter which may be used in the system for delivery of an additive.

[0031] FIG. 4 illustrates an alternative embodiment of the flow meter which may be used
5 in the system for delivery of an additive.

[0032] FIG. 5 illustrates the flow control system incorporating the flow meter which may be used in the system for delivery of an additive.

[0033] FIG. 6 illustrates the workflow of the flow control system which may be used in the system for delivery of an additive.

[0034] FIG. 7 illustrates a mechanical actuator at one position for use with the flow meter
10 which may be used in the system for delivery of an additive.

[0035] FIG. 8 illustrates the mechanical actuator of FIG. 7 at a second position for use with the flow meter which may be used in the system for delivery of an additive.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0036] The subject matter of the present invention is described with specificity; however,
15 the description itself is not intended to limit the scope of the invention. The subject matter thus, might also be embodied in other ways, to include different steps or combinations of steps similar to the ones described herein, in conjunction with other present or future technologies. Moreover, although the term “step” may be used herein to describe different elements of methods
20 employed, the term should not be interpreted as implying any particular order among or between various steps herein disclosed unless otherwise expressly limited by the description to a particular order. While the present invention may be applied in the oil and gas industry, it is not limited thereto and may also be applied in other industries to achieve similar results.

[0037] The present invention does away with the need for an external power supply, or supplies, to support a fluid additive delivery system to be used in connection with a flowing fluid, and which ensures proper mixing of the additive. The present invention can be operated independent of any external power supply, generating electrical power from the flowing fluid to which the additive is to be injected. In addition to avoiding the need for external power, the system further has a reduced footprint. The present invention may be operated with a plurality of additive pumps, driven by a gearhead assembly from the fluid motor's output shaft to provide the opportunity to select multiple additive fluids to be added, or to select one additive fluid from a variety of choices, or a combination thereof. The present invention also provides for thorough blending of additive(s) to the flowing fluid by introduction of the additive(s) to the fluid upstream of the fluid motor, encouraging mixing as the fluid passes through the high shear rotary motion of the vanes in the fluid motor.

[0038] Referring to FIG. 1, the fluid-additive delivery system 100 includes a fluid motor 102, a speed sensor 110, an electricity generation and storage system 111, a clutch 118, an additive pump 120, and a flow meter 124, where the fluid motor 102 and the flow meter 124 are in fluid communication with a piping 108 of the fluid 142 to which the fluid additive 140 is to be added. Preferably, the fluid 142 is a fuel and the fluid additive 140 to be added is a fuel additive.

[0039] The fluid motor 102 includes a fluid inlet 104 and a fluid outlet 106. The fluid inlet 104 permits the fluid 142 from the piping 108 to enter the fluid motor 102. The fluid outlet permits the fluid motor 102 to expel the fluid 142 after consumption of some of the kinetic energy of the fluid 142. The fluid motor 102 has an output shaft 126 rotatably driven by the fluid 142 as it moves through the motor and around the motor's vanes before exiting through the fluid output 106.

[0040] The speed sensor 110 is adapted to be associated with the output shaft 126 of the fluid motor 102 and to provide a signal to a computer 116 indicative of rotational speed of said output shaft 126. While the speed sensor may be directly mounted on the output shaft 126, it may alternatively be mounted to a shaft related to the output shaft through a gear assembly. The speed sensor may be selected from any known in the art, such as visual encoders, but preferably is a Hall-effect sensor.

[0041] The electricity generation and storage system 111 provides the on-board power for the delivery system 100. Preferably, the electricity generation and storage system includes a direct current generator 112, driven by the output shaft 126 of the fluid motor 102, for generation of electricity connected to an electrical battery 114 to store the generated electricity. Preferably the direct current generator 112 is mounted to the output shaft 126 of the fluid motor 102, but it may alternatively be mounted to a shaft related to the output shaft through a gear assembly.

[0042] For each fluid additive 140 available, and therefore for each additive pump 120, a clutch 118 is associated with the output shaft 126 of the fluid motor 102. While the clutch may be directly mounted to the output shaft 126 of the fluid motor 102, where multiple additive pumps 120 are desired so as to provide various additives, or where a gear reduction is desired, the clutch 118 may be mechanically coupled to the output shaft 126 by a gear assembly or serpentine belt to provide a multiple output gear head assembly intermediate the output shaft 126 of the fluid motor 102 and clutch 118. When activated by a computer 116, the clutch 118 is adapted to engage the shaft 150 of an additive pump 120 to provide power thereto, and thereby cause a fluid additive 140 to be pumped into the system. While the clutch 118 may be selected from among those known in the art, preferably it is a momentary wrap spring clutch. Similarly, the clutch 118 may be engaged by various actuators, but preferably is engaged by a solenoid

operator. The clutch **118** may draw power from various sources, but preferably is powered by the electricity generation and storage system **111**.

[0043] Each additive pump **120**, in fluid communication with a reservoir **122** of fluid additive **140**, is adapted to be rotatably driven by the output shaft **126** of the fluid motor **102** upon engagement by the clutch **118** and to pump the associated fluid additive **140** from the reservoir **122** to a flow meter **124**. Thus, each additive pump **120** is driven mechanically through its connection to the fluid motor **102**, requiring no external power. Fluid additive **140** may be a fluid additive, or may be a solid additive in a fluid carrier. Unlike the prior art, which required the fluid additive **140** to be directed at high pressure such as 165 psi (1,137.63 kPa), additive pump **140** provides fluid at a lower pressure, sufficient to provide injection into the fluid **142**. This may be a pressure equivalent to the pressure of fluid **142** in piping **108**, which may be at any pressure less than 150 psi (1,034.21 kPa), but is preferably around 60 psi (413.69 kPa). As a low pressure system is less prone to leaks and to fluid passing around components, the system is more accurate.

[0044] The computer **116** may be any of those known in the art, including a programmable logic controller (PLC). The computer **116** may draw electrical power from various sources, but preferably is powered by the electricity generation and storage system **111**.

[0045] Each flow meter **124** associated with an additive pump **120** has a meter fluid input adapted for fluid communication with the associated fluid pump **120** to permit communication of the fluid additive therefrom. Each flow meter **124** further has a meter fluid output adapted for fluid communication of the fluid additive **140** to the fluid **142** in said piping **108**, necessarily upstream of the fluid motor **102** rather than from piping associated with the fluid output **106** of the fluid motor **102**. This introduction of fluid additives **140** upstream of the fluid motor **102**

ensures the additive fluid **140** is well mixed as the fluid **142** passes through the high shear rotary motion of the vanes in the fluid motor **102**. Each flow meter **124** is adapted to provide a signal to the computer **116** indicative of the actual flow rate from said additive pump **120**, to permit quantification of the amount of additive fluid **140** provided and the actual flow rate of that provision. The flow meter **124** may be selected from various flow meters known in the art, but preferably is a positive displacement reciprocating flow meter, which may be adapted to reciprocate by solenoid operators or actuators. The flow meter **124** may be powered by various sources, but preferably is powered by the electricity generation and storage system **111**.

[0046] Ideally, the flow meter **124** provides instantaneous flow rate data, regardless of the volume used. The flow rate of additive **140** may be reported as a factor of volumetric displacement reflected in linear dimensions or in elapsed time, such as the one described herein.

[0047] In operation, the system **100** operates when a fluid **142** flows through a piping **108** into the fluid motor **102**, through its fluid inlet **104**. The fluid **142** causes the output shaft **126** of the fluid motor **102** to rotate before exiting the fluid motor through the fluid output. The speed sensor **110**, but by virtue of its association with the output shaft **126**, such as being mounted thereon, provides a signal to the computer **116** indicative of the rotational speed of the output shaft **126**. Due to the fixed volumes involved, the rotational speed of the output shaft **126** also reflects the volumetric displacement of the fluid motor **102**. Concurrently, the system **100** generates and stores electricity to power the system **100** by virtue of a direct current generator **112** mounted to or associated with the output shaft **126** (which may exit the fluid motor at one or both ends), which generates electricity during rotation of the output shaft **126**, which is then stores in an electrical battery **114**. Power is also taken from the output shaft **126** of the fluid motor **102** when a clutch **118**, attached to the output shaft **126**, controlled by the computer **116**

and powered from the battery 114, engages the shaft 150 of an additive pump 120. When engaged by the clutch 118, the additive pump 120 draws the selected fluid additive 140 from a reservoir 122 of the fluid additive 140 and pumps it to a flow meter 124. The flow meter 124, preferably a positive displacement reciprocating flow meter, caused to reciprocate by a computer, including computer 116, or by mechanical means at the end of each stroke, receives the discharge from the additive pump 120, preferably via a one-way valve, sends a signal to the computer 116 indicative of the actual flow rate from the additive pump to ensure the desired volume of the selected additive is provided. The fluid additive 140 then is discharged from the flow meter 124 upstream of the fluid motor 102, wherein the fluid additive is vigorously mixed by the vanes of fluid motor 102.

Flow meter device

[0048] The present invention may incorporate a flow meter involving the use of magnetically-coupled and sensitive devices to provide precise data to provide an instantaneous high resolution flow meter for monitoring the flow rate of a fluid in real time, even when measured in relatively small units and/or to precisely dispense relatively small volumes of liquid. The flow rate determination provided by the flow meter may be used to control the flow rate of fluid into the flow meter prior to disbursement of the fluid. Similarly, the control over minute volumes of liquid may be used to control the volume of fluid disbursed.

[0049] Preferably, as identified in FIG. 2, the improved flow meter 124 performs these functions with high resolution by providing a novel positive-displacement flow meter 202 in fluid communication with a valve system 204 to prompt reciprocation of a piston within the cylinder 232 of the flow meter 202. The cylinder 232 has a cylinder first end 220 and a cylinder second end 222, and a first end connector 224 at or about the cylinder first end 220 and a second

end connector **226** at or about the cylinder second end **222**. The flow meter **202** may also include a guide **320** intermediate the cylinder **232** and the transducer **230**, and parallel to both. Preferably the cylinder **232**, the connectors **224**, **226**, and the other fluid-conducting components including the orifices through the valve system **204**, the fluid input **208** and the fluid output **210** are of a large diameter compared to the size of particulates carried in or constituting the fluid, providing a ratio of at least 20:1.

[0050] The flow meter **202** may include a controller **206**, preferably a programmable logic controller (PLC), receiving signals from the positive-displacement flow meter **202** to identify the flow rate of the fluid. Operation of the valve system **204** may be controlled by any of various types of controllers known in the art, for example, such as with the controller **206** or with a mechanical valve controller drive by the actual flow through the flow meter **202**. Positioned near and in alignment with the cylinder **232** is a linear digital encoding transducer **230**. Associated with both the cylinder **232** and the transducer **230** is a coupling arm **218**, having a coupling arm first end **236** and a coupling arm second end **228**.

[0051] The valve system **204** associated with the invention includes a fluid input **208**, having a fluid output **210**, in fluid communication **212**, **214** with a first end connector **224** of the cylinder **232** and in fluid communication with a second end connector **226** of the cylinder **232**, respectively. This may be a two-position valve, or a combination of valves providing the same effect. As illustrated in FIG. 2, the valve system **204** is preferably a four-way, two-position valve positioned by two opposing actuators **234**, preferably solenoids, although two three-way, two-position valves could be used. Alternatively, the second actuator **234** may be replaced with a spring return. Thus, the valve system **204** is switchably operable among a first position **246** and a second position **248**. Switching may be accomplished by one or more solenoid actuators **234** or

by other actuators. Preferably, the valve system **204** includes solenoid valves, preferably of the self-cleaning poppet type as these do not utilize wearing surfaces, thus providing a longer system life.

[0052] By virtue of the accuracy of the transducer **230**, the controller **206** may determine
5 the position of the coupling arm **218** relative to the linear digital encoding transducer **230** at all positions between the cylinder first end **220** and the cylinder second end **222**, and may do so in connection with identification of an associated point in time. Beneficially, as the displacement of the piston **304** may be measured by the transducer **230** and as the cross sectional area of the interior of the cylinder **232** is a fixed and known value, the displacement of the piston **304** as
10 measured by the transducer **230** defines the volume of any fluid passing through the system. Thus, the transducer **230** functions like a micrometer, simply telling the system where the piston **304** is relative to the end of the cylinder **232**. As the system (program) knows what the displacement of the cylinder is, a linear unit of measurement therefore represents a fixed amount of fluid. As the distance from the beginning of the stroke is reported, the system knows how
15 much fluid has been displaced. The linear transducer **230** thus serves as a device to measure distance, where distance is directly proportional to volume based on the displacement of the cylinder **232**. Alternatively, the controller **206** may record positions of the coupling arm second end **228** relative to the transducer **230** at associated points in time and may thus determine the speed and direction of movement of the coupling arm second end **228** as a function of change in
20 said position per change in time. The cross-sectional internal area of the cylinder **232** is fixed and constant throughout, so this data also provides the change in volume per unit time, and thus the actual flow rate of the fluid therethrough.

[0053] Referring to FIG. 3, the positive displacement flow meter **202** includes a cylinder

232, a ferrous floating internal piston 304, a cylindrical ring 306 slidably positioned about and closely encircling the cylinder 232, a linear digital encoding transducer 230, and a coupling arm 218 integrally and fixedly associated with the cylindrical ring 306 at its coupling arm first end 236 so as to function as a single unit therewith and in association with the transducer 230. The coupling arm 218 and the cylindrical ring 306 may be constructed as a single unit and may be formed or created as a single piece.

[0054] The cylinder 232 and internal piston 304 are necessary constituents of a positive displacement reciprocating piston flow meter 202. The cylinder 232, composed of a non-ferrous material, has length 312, a cylindrical (circular tubular) exterior 314, and a cylinder centerline 316. The cylinder 232 also has a cylinder axis 322 at the cylinder centerline 316 along the cylinder's length 312. The internal piston 304, composed at least in part of a ferrous material and preferably generates a magnetic field, is freely slidable within the cylinder 232 between the cylinder first end 220 and the cylinder second end 222. The outer surface of the piston 304 is fitted sufficiently close to the interior of the cylinder 232 to preclude appreciable leakage between the two resulting chambers 328, 330 divided by the piston 304. The piston 304 further has a length 332 sufficient to prevent the piston from binding during movement and thus to maintain its relationship to the cylinder axis 322. The cylindrical ring 306 is slidably positioned about and closely encircles the cylinder exterior 314, thus capable of sliding along the cylinder exterior 314 without binding and maintained substantially concentric about the cylinder axis 322. The cylindrical ring 306 is composed of magnetic material to magnetically couple to the ferrous floating internal piston 304, but could alternatively be of a ferrous material if the piston generates a magnetic field. Thus, as the piston 304 travels within the cylinder 232, the cylindrical ring 306 likewise travels and maintains its position relative to the piston 304. Preferably, a low-friction

material 308, such as a Teflon® ring, may be positioned or inserted between the cylindrical ring 306 and the cylinder 232 to support the cylindrical ring 306, and to maintain the cylinder ring 306 centered about the cylinder 232. Preferably, the low friction material 308 is constructed as a ring to fit within the cylindrical ring 306, but alternatively may be constructed as a sleeve about the cylinder 232. Alternatively the cylinder exterior 314 and the interior of the cylinder ring 306 may each have a low coefficient of friction so the cylinder ring 306 may freely slide and not be susceptible to increased and undesirable friction by a small number of particulates. Additionally, the cylinder exterior 314 or the interior of cylinder ring 306 may be lubricated to reduce friction.

[0055] A linear digital encoding transducer 230, preferably absolute, having a transducer length 336 and a transducer axis 338 along its length is also provided. The transducer axis 338 is substantially parallel (preferably parallel) to the cylinder axis 322. The transducer length 336 is generally equivalent to the cylinder length 312. Preferably, the transducer axis 338 is generally parallel to the cylinder axis 322.

[0056] The coupling arm 218 may be integrally affixed to or formed with the cylindrical ring 306 at the coupling arm first end 340 so as to function, preferably permanently, as a single unit therewith and maintained generally perpendicular to the cylinder axis 322. The coupling arm 310, which may be constructed of a ferrous metal, includes a magnetic section 344, which may be a magnet 350 or a magnetized section, at the coupling arm second end 228 of sufficient strength to generate a magnetic field contacting or interacting with the linear digital encoding transducer 230 as it rides over or about the transducer 230 to indicate the position of the coupling arm 218 (and thus the cylindrical ring 306) relative to the transducer 230. This may be accomplished by a single arm riding adjacent the transducer 230 or by a section of coupling arm second end 228 or a cylindrical ring integrally affixed to or formed with the cylindrical ring 306

at the coupling arm second end **228** so as to function, preferably permanently, as a single unit therewith, having an opening to encircle the transducer **230**. By avoiding a mechanical couple between the piston **304** and the transducer **230**, seals through the cylinder first end **220** or the cylinder second end **222** are avoided, particularly as each seal are prone to leakage and may
5 result in unequal operation as the piston **304** reciprocated in the cylinder **232**. By avoiding a mechanical couple, the risk of contact by the couple with other metal components, a fire hazard, and the need for additional components to transform the mechanical couple's movement to movement along the transducer **230** are avoided.

[0057] Positioning the transducer **230** separate from the cylinder **232**, rather than directly
10 in contact or immediately adjacent, is necessary for the accuracy of the transducer **230**. Positioning the transducer **230** separate from the cylinder **232** ensures the magnetic field of the internal piston **304** does not interfere with the accuracy of the transducer **230**, which utilizes a magnetic field to determine the slightest change in position of the internal piston **304** via the coupling arm **218**. Separation, together with the transducer-encircling segment of coupling arm
15 second end **228**, provides accurate readings, particularly of the accuracy needed incident to the potentially quite low flow rates involved. This is particularly important as the transducer **230** necessarily must provide a high degree of accuracy with respect to each movement of the piston **304**, preferably in the precision of about 1/1,000 (0.0025 cm) of an inch of travel, rather than the per cycle signal associated with the prior art. The movement over the transducer may be of a
20 length selected in light of the fluid, flow rate and length of stroke desired in the flow meter, whether it be 3 inches (7.62 cm), 10 inches (25.40 cm) or 20 inches (50.80 cm).

[0058] Since the floating internal piston **304** and coupling arm **218** are magnetically coupled, as the floating internal piston **304** moves along the length of the metering cylinder **232**,

the coupling arm **218** is carried precisely at the same relative position along the length **336** of the linear digital encoding transducer **230**. The linear digital encoding transducer **230** translates the relative position of the magnetic section **344** of the coupling arm **218** into an electrical signal which is communicated to the controller **206**, which may be a programmable logic controller.

5 **[0059]** A guide **320** is preferably used and positioned intermediate the cylinder **232** and the transducer **230**, and parallel to both. The guide **320** limits the motion of the coupling arm **218** to a plane parallel to both the cylinder **232** and the transducer **230**, reducing the likelihood of the coupling arm **218** binding about the cylinder **232** and the transducer **230**. This limitation may be accomplished, for example, by the coupling arm **218** encircling the cross section of the
10 guide **320** as depicted in FIGS. 2 and 3, or the coupling arm **218** having a track on its periphery mating to the guide **320**. The guide **320** may provide a low friction point of contact and may be a flat plate. Regardless of its construction, the guide **320** maintains the magnetic section **344** of the coupling arm second end **228** about the transducer **230**, preferably concentrically, without contacting the transducer **230**.

15 **[0060]** Referring again to FIG. 2, the controller **206** may also control the valve system **204** to reciprocate the ferrous floating internal piston **304** between the cylinder first end **220** and the cylinder second end **222** at least when the piston **304** approaches, nearly reaches or reaches the cylinder first end **220** or the cylinder second end **222**. The valve system **204** may accomplish this by generating an electric pulse to cause one of the solenoids **234** or another actuator **234** to
20 change position.

[0061] Alternatively, as illustrated in FIG. 4, the cylinder **232** may have, exiting through either its cylinder first end **220** or its cylinder second end **222**, a first rod **402** coupled to the valve system **204** at an actuator **234** to effect flow reversal at the end of the stroke, that is when

the piston **304** reaches or nearly reaches the cylinder first end **220** or the cylinder second end **222**. A matching second rod **403**, not coupled to any device, would necessarily exit the cylinder **232** at its opposite side and be similarly related to the piston **304** to ensure the volumes of the two chambers **328**, **330**, and therefore their displacement, are equivalent. The first rod **402** is preferably coupled to the piston **304** to ensure motion in both directions, but could be loaded, such as by a spring, to move with the piston **304**. In one embodiment, this could be accomplished with a snap action, spring-loaded shifter to work with a single actuator, such as depicted in Figs. 7 and 8. Alternatively, a three-way valve could be coupled to each of the two rods **402**, **403** to effect operation.

[0062] With reference to FIGS. 7 and 8, an automatic shifting mechanism **700**, that shifts the valve system **204** via and in response to the movement of first rod **402** among the first position **246** and the second position **248**, thus also reversing the direction of movement of the piston **304** in the flow meter **202**.

[0063] As shown in more detail in FIG. 7, yoke **706** and a lever **710** are commonly mounted on a bushing **716** fixed to a stationary standard **714**. The yoke **706** is shown in a retracting (not upward) position. Yoke **706** and lever **710** are free to independently rotate about bushing **716**, except that a torsion spring **708** resiliently couples the free end of lever **710** with an internal arm **718** in yoke **706**. The free end of lever **710** is coupled to linkage arm **720** by ball joint connection **712**. Pin **702**, located at the end of first rod **402**, is captured and slides within a narrow neck **704** of yoke **706** and causes yoke **706** to rotate about bushing **716**.

[0064] In FIG. 7, first rod **402** has reached its outermost limit of travel, and the yoke **706** has actuated to cause lever **710** to be in the downward position. The flow meter **202** has reversed and first rod **402** reverses direction, retracting. As pin **702** moves toward flow meter **202**, yoke

706 rotates clockwise about bushing 716, causing internal arm 718 to rotate clockwise. Such clockwise rotation compresses torsion spring 708. The force exerted by torsion spring 708 upon ball joint 712 is still in the direction of retraction. As the first rod 402 approaches its point of travel furthest in retraction, the internal arm 718 is horizontally aligned with ball joint 712 and torsion spring 708 is at maximum compression. Any further motion toward flow meter 202 by first rod 402 causes torsion spring 708 to present an outward force on ball joint 712, which rapidly snaps to its upper position, thereby changing the positions of valve system 204 and changing the direction of fluid flow into flow meter 202.

[0065] FIG. 8 shows yoke 706 of the automatic shifting mechanism in the retracted position. As first rod 402 extends, the torsion spring 708 compresses against ball joint 712 in the outward direction until internal arm 718 is horizontally aligned (i.e. reaches minimum distance) with ball joint 712. Ball joint 712, carrying linkage arm 720 then snaps back into the retracting position, thus completing the cycle.

[0066] Referring again to FIGS. 2 and 3, since the change in volume of each chamber 328, 230 of the metering cylinder 232 is calculated based on change in position, each thousandths of an inch (or 0.0025 cm) in length, or any small unit of length, of each chamber 328, 230 the metering cylinder 202 corresponds to a position on the linear digital encoding transducer 230, and therefore accurately represents the flow passing through the flow meter loop 216. Preferably, when the floating internal piston 304 reaches an end of the metering cylinder 220, 222, and when the controller 206 is used to control the valve system 204, the signal from the linear digital encoding transducer 230 as processed by the controller 206 to effect a change in position of the valve system 204 among the first and second positions 246, 248 (such as by activating the solenoid actuator 234 to change its position), changing the direction of flow from

one end of the metering cylinder to the opposite end **220**, **222**.

[0067] Thus, in operation the fluid from the fluid input **208**, and the associated pressure, entering the metering cylinder **232** works against the floating piston **304**, and drives the fluid on the opposing, and now discharging, side of the floating piston **304** to be discharged by valve system **204**. This is accomplished by ensuring in the first position **246**, the fluid input **208** is connected to the second end connector **226** and the first end connector **224** is connected to the fluid output **210**. In the second position **248**, the fluid input **208** is connected to the first end connector **224** and the second end connector **226** is connected to the fluid output **210**, thus reversing the flow of fluid through the flow meter loop **216**, and reversing the direction of movement of the piston **304**.

[0068] Due to the large diameter of the metering cylinder **202** and the orifice diameters throughout the meter, the flow meter **202** is very tolerant of solids and abrasives and thus provides longer life in addition to improved accuracy. Thus, the flow meter **202** is unique in that it does not rely on close tolerance meshing machined parts in order to measure the flow of fluid.

Flow meter incorporating flow control system

[0069] Because the flow meter **202** provides precise determination of the flow rate of a fluid and/or volume of distribution, it may be incorporated into a flow control system **500**, such as depicted in FIG. 5, for use in the present system such that the fluid output **210** from the flow meter **202** may be discharged where desired, including being introduced into a second fluid **502** as an additive for blending.

[0070] The flow control system **500** integrates the flow meter **202** intermediate a source **504** of fluid and a destination **550**. The source **504** of fluid to be metered, such as an additive, in a supply **506** may be connected to the fluid input **208** of the flow meter **202** and may be

permitted to introduce the fluid to the fluid input **208**. The controller **206** may then provide an output signal consistent with the associated flow rate to a flow controller **508**, operable at least among a fluid flowing position and a fluid non-flowing position, intermediate the supply **506** and the valve system **204**. The flow controller **508** may be a computer-controlled pump, including
5 one operable among a plurality of pump speeds, or a valve. The fluid supply **506** may be any type of fluid source, including one flowing and one of fixed volume, which may or may not be under pressure. Here the fluid supply **506** is the output from the additive pump **120**. The destination **550**, in communication with the output **210** from the valve system **204** (preferably through an injection point check valve **552** to prevent contamination or backflow pressure in the
10 system) may be another volume, a container, or even a flow of untreated fluid for introduction of an additive or for blending. Here the destination **550** is the piping **108**.

[0071] In operation, the flow control system **500** may be employed to ensure the desired flow rate of an additive fluid is actually obtained. This may be accomplished by the flow control workflow **600**.

15 [0072] At step **602**, the system receives a user input for said desired flow rate of additive fluid and a desired quantity.

[0073] At step **604**, the system activates the additive flow controller **508** at a presumed flow rate consistent with said desired flow rate of additive fluid.

20 [0074] At step **606**, the system introduces the additive fluid at presumed flow rate to the flow meter **202** via the valve system **204** as controlled by the controller **206**.

[0075] At step **608**, controller **206** determines the actual flow rate via the movement of the ferrous floating internal piston **304**, i.e. based on position related to displacement (particularly based on the relative position along the length of the transducer), and provides at

least one output signal consistent with the actual associated flow rate to the system.

[0076] At step 610, the system determines if the actual flow rate is within the margin of error of the desired flow. If the actual flow rate is within the margin of error of the desired flow rate, the system proceeds to step 614. Otherwise, the system continues to step 612.

5 [0077] At step 612, the system adjusts the actual flow rate at said additive flow controller 408508 to obtain the desired flow rate from step 602.

[0078] At step 614, the system determines if the desired quantity of additive fluid has been provided, which may be based on the actual flow rate(s) and elapsed time(s) or may be based on the displacement of the piston 304 as measured by the transducer 230. If the system
10 determines if the desired quantity of additive fluid has been provided, the method ends. If not, the system returns to step 608.

[0079] The resulting system 500 may provide delivery of the fluid to ensure delivery from a flowing supply of a fluid into a flow of a second fluid at a low ratio consistent with additive treatment. Thus, the output of the additive pump 120 may be verified and controller
15 with a unique flow meter to ensure the appropriate volume of additive

[0080] While the present invention has been described in connection with presently preferred embodiments, it will be understood by those skilled in the art that it is not intended to limit the invention to those embodiments. It is therefore, contemplated that various alternative embodiments and modifications may be made to the disclosed embodiments without departing
20 from the spirit and scope of the invention defined by the appended claims and equivalents thereof.

CLAIMS

I claim:

1. A fluid-additive delivery system for addition of a fluid additive to a fluid flowing in a piping, comprising,

a fluid motor, said fluid motor having a fluid inlet and a fluid outlet, said fluid motor adapted to receive said fluid from said piping at said fluid inlet, said fluid motor adapted to expel said fluid at said fluid output, and said fluid motor having an output shaft rotatably driven by said fluid moving between said fluid inlet and said fluid output;

a speed sensor adapted to be associated with said output shaft, said speed sensor adapted to provide a signal to a computer indicative of rotational speed of said output shaft;

an electricity generation and storage system, said electricity generation and storage system comprising a direct current generator and an electrical battery, said direct current generator adapted to be driven by said output shaft, said direct current generator adapted to provide electricity to said electrical battery;

a clutch adapted to be associated with output shaft, said clutch adapted to engage a shaft of an additive pump upon activation by a computer;

said additive pump adapted to be rotatably driven by said output shaft upon engagement by said clutch, said additive pump in fluid communication with a reservoir of fluid additive and adapted to pump said fluid additive to a flow meter; and

said flow meter having a meter input adapted for fluid communication with said additive pump, said flow meter having a meter output adapted for fluid communication of said fluid additive to said fluid in said piping, said flow meter adapted to provide a signal to said computer indicative of the actual flow rate from said additive pump.

2. The delivery system of claim 1, wherein said speed sensor comprises a Hall-effect speed sensor.
3. The delivery system of claim 1, wherein said clutch is momentary wrap spring clutch.
4. The delivery system of claim 3, wherein said clutch is engaged by a solenoid operator.
5. The delivery system of claim 3, wherein said clutch is electrically powered by said electricity generation and storage system.
6. The delivery system of claim 1, wherein said computer is adapted to be electrically powered by said electricity generation and storage system.
7. The delivery system of claim 1, wherein said computer is a programmable logic controller.
8. The delivery system of claim 7, wherein said computer is adapted to be electrically powered by said electricity generation and storage system.
9. The delivery system of claim 1, wherein said flow meter is a positive displacement reciprocating flow meter.

10. The delivery system of claim 9, wherein said flow meter is adapted to reciprocate by solenoid operators powered by said electricity generation and storage system.
11. The delivery system of claim 9, wherein said flow meter is adapted to reciprocate by electrical powered by said electricity generation and storage system.
12. The delivery system of claim 1, further comprising a multiple output gear head intermediate said output shaft and said clutch.
13. The delivery system of claim 12, further comprising
- a second clutch, said second clutch adapted to be associated with output shaft, said second clutch adapted to engage a shaft of a second additive pump upon activation by a computer, said second clutch connected to said multiple output gear head;
 - said second additive pump adapted to be rotatably driven by said output shaft upon engagement by said second clutch, said additive pump in fluid communication with a second reservoir of a second fluid additive and adapted to pump said second fluid additive to a second flow meter; and
 - said second flow meter having a second meter input adapted for fluid communication with said second pump, said second flow meter having a second meter output adapted for fluid communication of said second fluid additive to said fluid in said piping, said second flow meter adapted to provide a signal to said computer indicative of the actual flow rate from said second additive pump.

14. The delivery system of claim 1, wherein said fluid flowing in a piping flows at a pressure of less than 150 psi (1,034.21 kPa) and said additive pump pumps said fluid additive to said flow meter at a pressure of less than 60 psi (413.69 kPa).

15. A fluid-additive delivery system for addition of a fluid additive to a fluid flowing in a piping, comprising,

a fluid motor, said fluid motor having a fluid inlet and a fluid outlet, said fluid motor in communication with said piping at said fluid inlet, said fluid motor in communication with said fluid output, and said fluid motor having an output shaft rotatably driven by said fluid moving between said fluid inlet and said fluid output;

a speed sensor associated with said output shaft, said speed sensor providing a signal to a computer indicative of rotational speed of said output shaft;

a direct current generator in mechanical connection with said output shaft, said direct current generator electrically connected to an electrical battery;

a clutch associated with said output shaft, said clutch engaging a shaft of an additive pump upon activation;

said additive pump rotatably driven by said output shaft upon engagement by said clutch, said additive pump in fluid communication with a reservoir of fluid additive and impelling said fluid additive to a flow meter; and

said flow meter having a meter input in fluid communication with said additive pump, said flow meter having a meter output in one-way fluid communication with said piping, said flow meter providing a signal to a computer indicative of the actual flow rate from said additive pump.

16. A flow meter, comprising:

a cylinder having a cylinder length, a cylinder exterior, a cylinder centerline, a cylinder first end and a cylinder second end, said cylinder having a cylinder axis at said cylinder centerline along said cylinder length, said cylinder having a first end connector and a second end connector, said cylinder composed of non-ferrous material;

a ferrous floating internal piston freely slidable in said cylinder between said cylinder first end and said cylinder second end, said piston having a piston length;

a cylindrical ring slidably positioned about and closely encircling said cylinder exterior, said cylindrical ring magnetically coupled to said ferrous floating internal piston, said cylindrical ring maintained substantially concentric with said cylinder axis;

an absolute linear digital encoding transducer having a transducer length and transducer axis, said transducer axis substantially parallel to said cylinder axis, said transducer length generally equivalent to said cylinder length;

a coupling arm having a coupling arm first end and a coupling arm second end, said coupling arm integrally affixed to said cylindrical ring at said coupling arm first end and maintained generally perpendicular to said cylinder axis, said coupling arm having a magnetic section at said coupling arm second end, said magnetic section having a magnetic field interacting with said linear digital encoding transducer;

a valve system having a fluid input, having a fluid output, in fluid communication with said first end connector and in fluid communication with said second end connector, said valve system switchably operable among a first position and a second position, said first position connecting said fluid input and second end connector and connecting said first end connector with said fluid output and said second position connecting said fluid input and said first end

connector and connecting said second end connector with said fluid output; and

a controller adapted to determine a plurality of the positions of said coupling arm relative to said linear digital encoding transducer, recording said plurality of positions and an associated time for said plurality of positions, determining the speed and direction of movement of said coupling arm relative to said linear digital encoding transducer as a function of difference in said position between said associated times; and

a valve system controller adapted to cause said valve system to reciprocate said ferrous floating internal piston between said cylinder first end and said cylinder second end at least when said piston approaches either said cylinder first end or said cylinder second end.

17. The flow meter of claim 16, wherein

said valve system controller is a computer;

said controller is a computer,

said controller is adapted to signal said valve system controller when said coupling arm reaches said cylinder first end or said cylinder second end and said valve system controller is adapted to cause said valve system to switch among said first position and said second position.

18. A flow control system for measurement of a flowing fluid substance, comprising:

a positive displacement reciprocating piston flow meter, said positive displacement flow meter having a first end connector and a second end connector, said positive displacement flow meter comprising:

a cylinder having a cylinder length, a cylinder exterior, a cylinder centerline, a cylinder first end and a cylinder second end, said cylinder having a cylinder axis at said

cylinder centerline along said cylinder length, said cylinder composed of non-ferrous material;

a ferrous floating internal piston freely slidable in said cylinder between said cylinder first end and said cylinder second end, said piston having a piston length;

a cylindrical ring slidably positioned about and closely encircling said cylinder exterior, said cylindrical ring magnetically coupled to said ferrous floating internal piston, said cylindrical ring maintained substantially concentric with said cylinder axis;

an absolute linear digital encoding transducer having a transducer length and transducer axis, said transducer axis substantially parallel to said cylinder axis, said transducer length generally equivalent to said cylinder length;

a coupling arm having a coupling arm first end and a coupling arm second end, said coupling arm integrally affixed to said cylindrical ring at said coupling arm first end and maintained generally perpendicular to said cylinder axis, said coupling arm having a magnetic section at said coupling arm second end, said magnetic section having a magnetic field interacting with said linear digital encoding transducer;

a valve system having a fluid input, having a fluid output, in fluid communication with said first end connector and in fluid communication with said second end connector, said valve system switchably operable among a first position and a second position, said first position connecting said fluid input and second end connector and connecting said first end connector with said fluid output and said second position connecting said fluid input and said first end connector and connecting said second end connector with said fluid output; and

a controller adapted to determine a plurality of the positions of said coupling arm relative to said linear digital encoding transducer, recording said plurality of positions and an associated

time for said plurality of positions, determining the speed and direction of movement of said coupling arm relative to said linear digital encoding transducer as a function of difference in said position between said associated times; and

a valve system controller controlling said valve system to reciprocate said ferrous floating internal piston between said cylinder first end and said cylinder second end at least when said piston approaches either said cylinder first end or said cylinder second end.

19. The flow control system of claim 18 wherein said flowing fluid substance is an additive fluid, and wherein said additive is to be introduced into a flow of untreated fluid at a ratio of less than 2500 parts per million of volume of said additive to volume of said untreated fluid.

20. The additive delivery system of claim 18 further comprising:
said controller providing an output signal consistent with said associated flow rate; and
an additive flow controller intermediate said supply of said additive and said valve system, said additive flow controller operable among at least an additive flowing position and an additive non-flowing position.

21. The flow control system of claim 18, wherein said additive flow controller is a computer-controlled pump.

22. The flow control system of claim 18, wherein said additive flow controller is a valve and said supply of said additive is pressurized.

23. The flow control system of claim 19 wherein said computer-controlled pump is operable among a plurality of pump speeds.

24. A method for obtaining a desired flow rate of fluid additive to a flow of untreated fluid at a ratio of less than 2500 parts per million of volume said fluid additive to volume of said untreated fluid, comprising:

- 1) receiving a user input for said desired flow rate of fluid additive;
- 2) activating an additive flow controller at a presumed flow rate consistent with said desired flow rate of fluid additive;
- 3) introducing the presumed flow rate to a positive displacement reciprocating piston flow meter, said positive displacement flow meter having a first end connector and a second end connector, said positive displacement flow meter comprising:

a cylinder having a cylinder length, a cylinder exterior, a cylinder centerline, a cylinder first end and a cylinder second end, said cylinder composed of non-ferrous material; said cylinder having a cylinder axis at said cylinder centerline along said cylinder length;

a ferrous floating internal piston freely slidable in said cylinder between said cylinder first end and said cylinder second end, said piston having a piston length;

a cylindrical ring slidably positioned about and closely encircling said cylinder exterior, said cylindrical ring magnetically coupled to said ferrous floating internal piston, said cylindrical ring maintained substantially concentric with said cylinder axis;

a linear digital encoding transducer having a transducer length and transducer axis, said transducer axis substantially parallel to said cylinder axis, said transducer

length generally equivalent to said cylinder length; and

a coupling arm having a coupling arm first end and a coupling arm second end, said coupling arm integrally affixed to said cylindrical ring at said coupling arm first end and maintained generally perpendicular to said cylinder axis, said coupling arm having a magnetic section at said coupling arm second end, said magnetic section having a magnetic field interacting with said linear digital encoding transducer;

a valve system having a fluid input from said flowing supply of said fluid additive, having a fluid output, in fluid communication with said first end connector and in fluid communication with said second end connector, said valve system switchably operable among a first position and a second position, said fluid input in communication with said flowing supply of an fluid additive, said fluid output in communication with said flow of untreated fluid, said first position connecting said fluid input and second end connector and connecting said first end connector with said fluid output and said second position connecting said fluid input and said first end connector and connecting said second end connector with said fluid output; and

a controller adapted to determine a plurality of the positions of said coupling arm relative to said linear digital encoding transducer, recording said plurality of positions and an associated time for said plurality of positions, determining the speed and direction of movement of said coupling arm relative to said linear digital encoding transducer as a function of difference in said position between said associated times; and

a valve system controller controlling said valve system to reciprocate said ferrous floating internal piston between said cylinder first end and said cylinder second end at least when said ferrous floating internal piston approaches either said cylinder first end or

said cylinder second end; and

4) comparing said presumed flow rate to said at least one output signal and identifying the deviation from desired flow rate; and

5) adjusting the actual flow rate at said additive flow controller to eliminate said deviation.

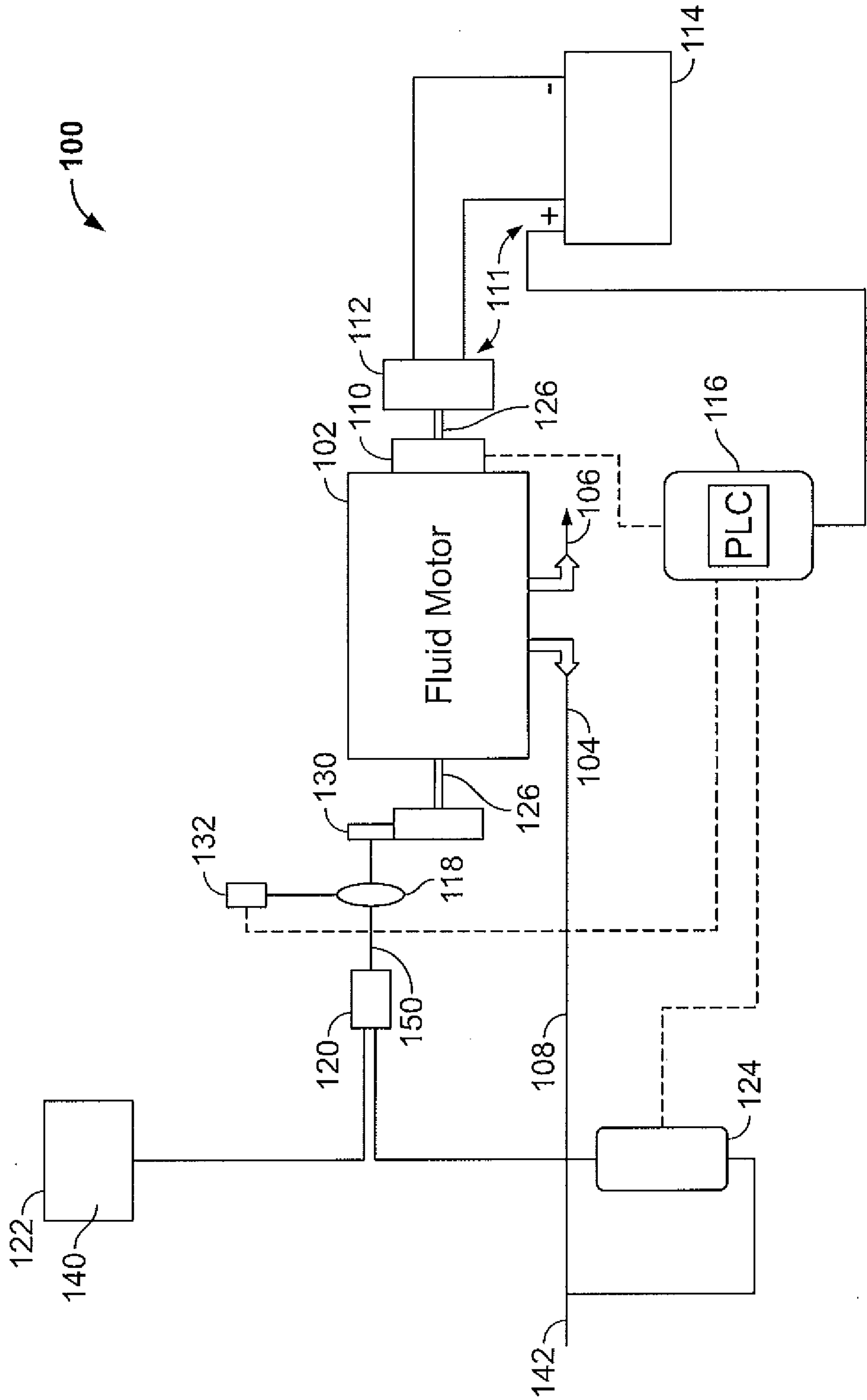


FIG. 1

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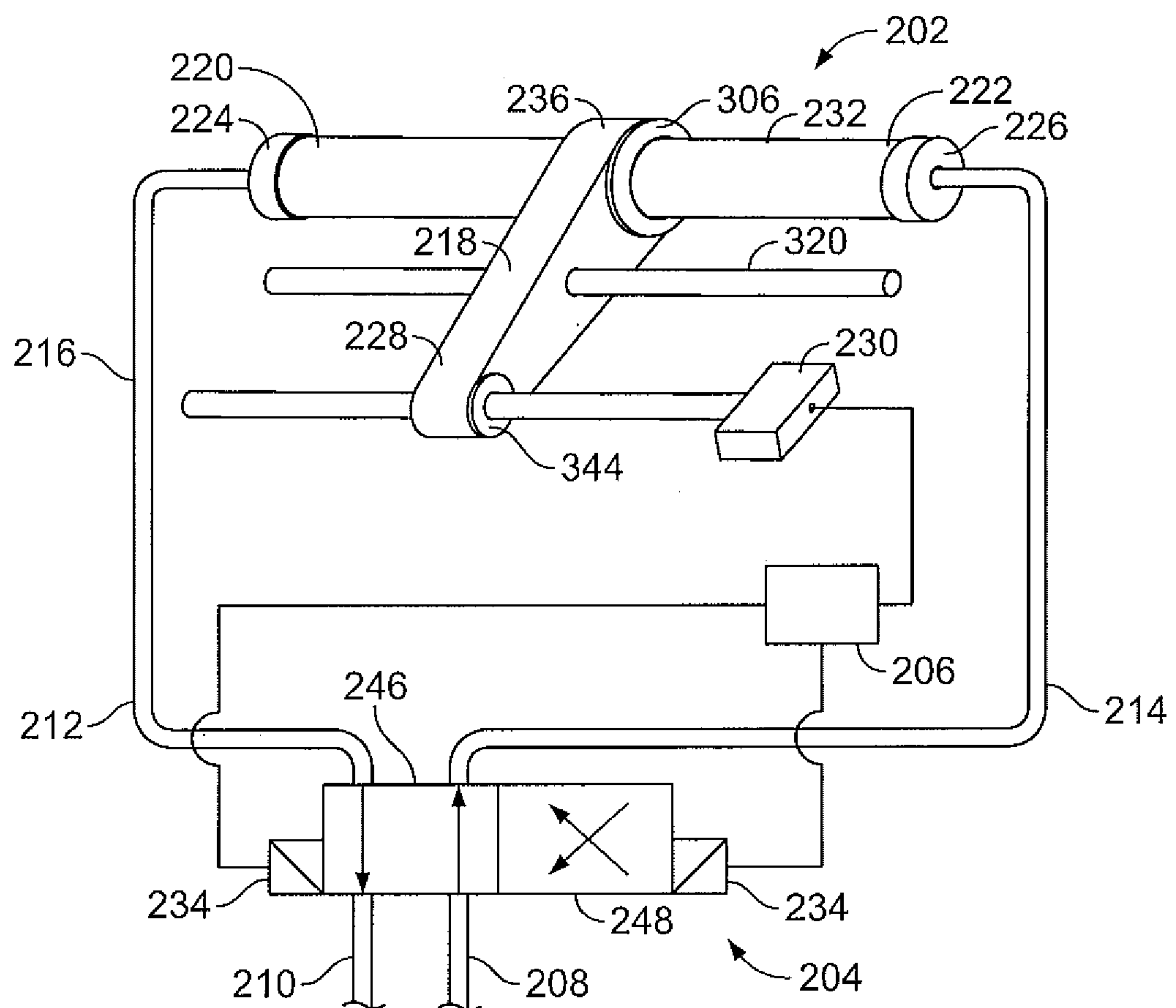
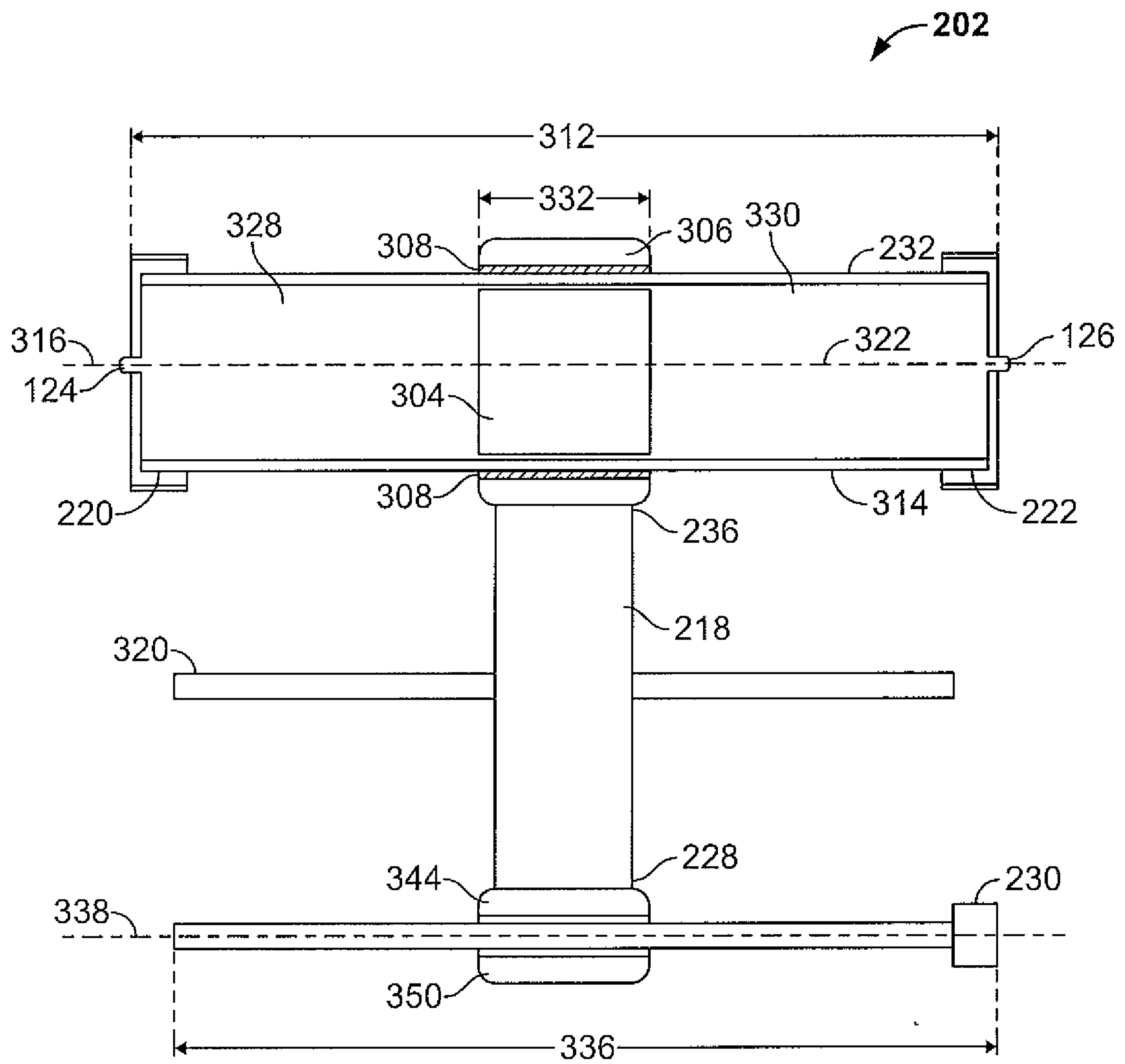


FIG. 2

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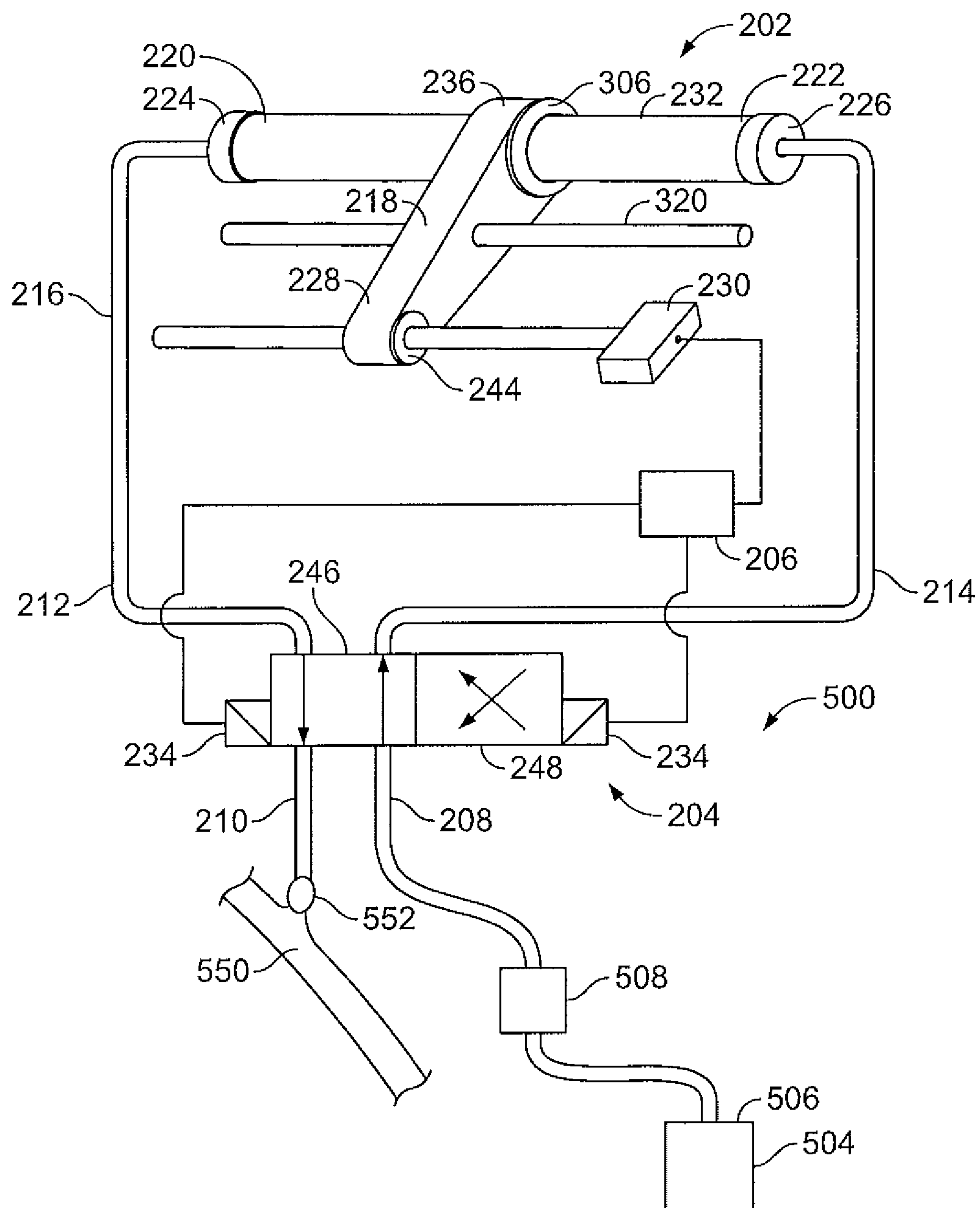
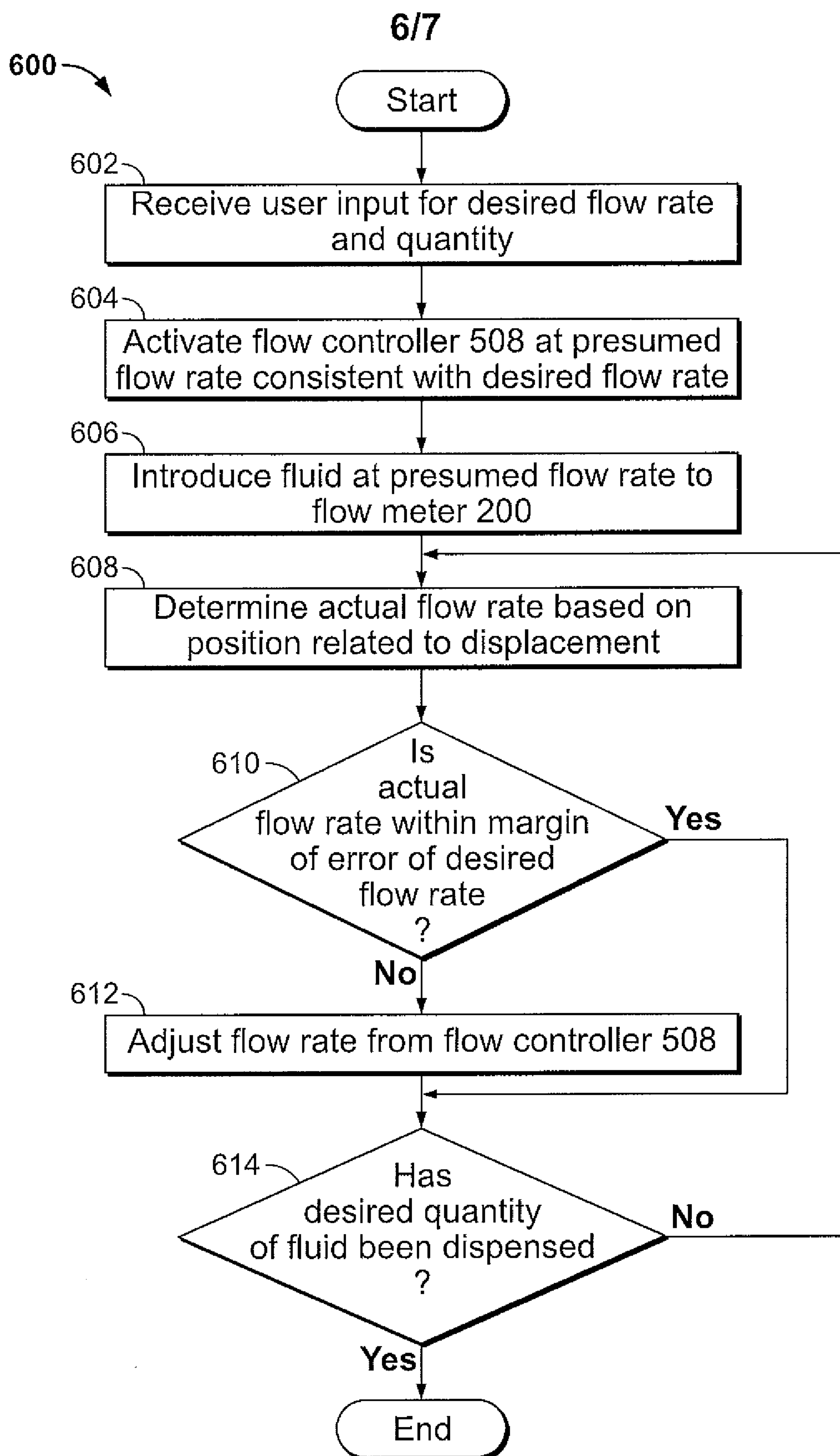


FIG. 5

**FIG. 6**

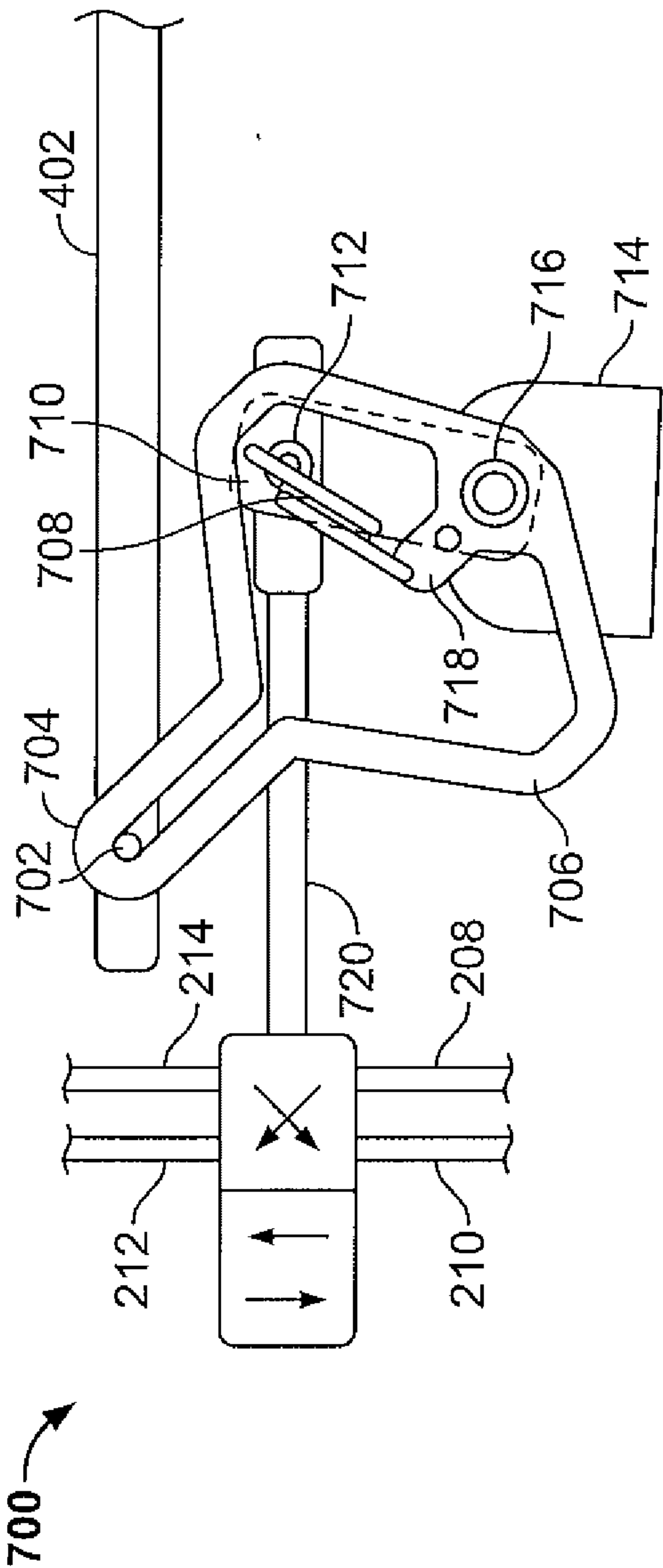


FIG. 7

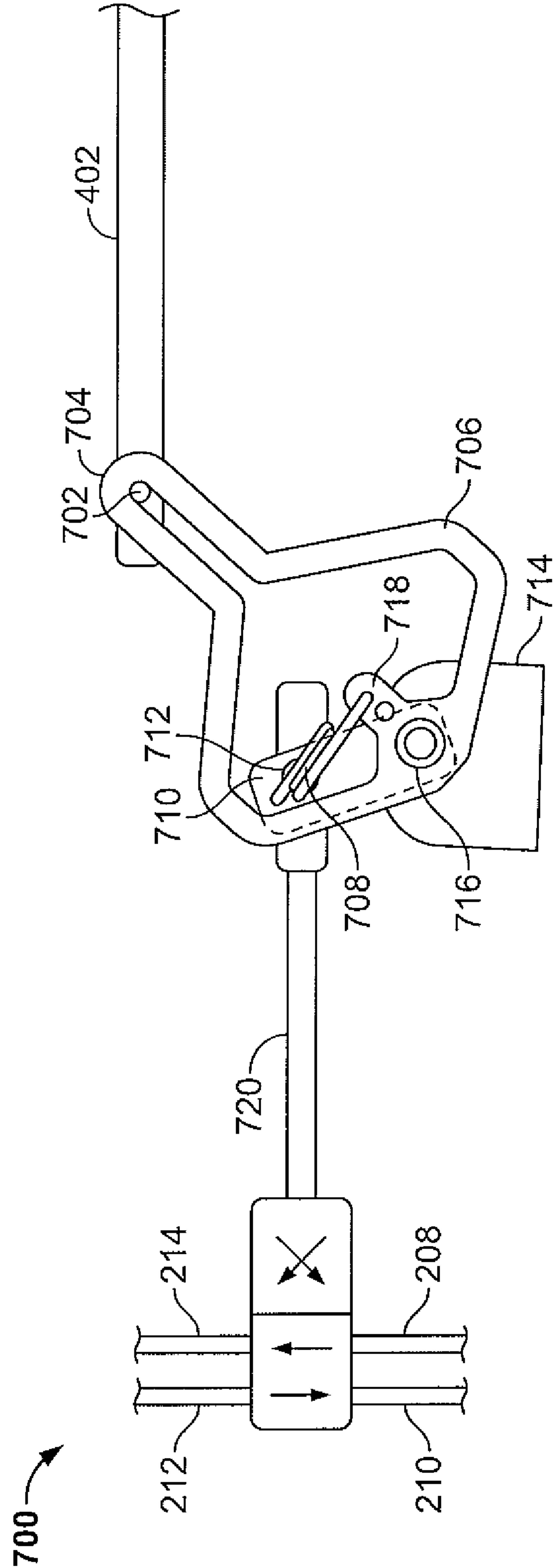


FIG. 8

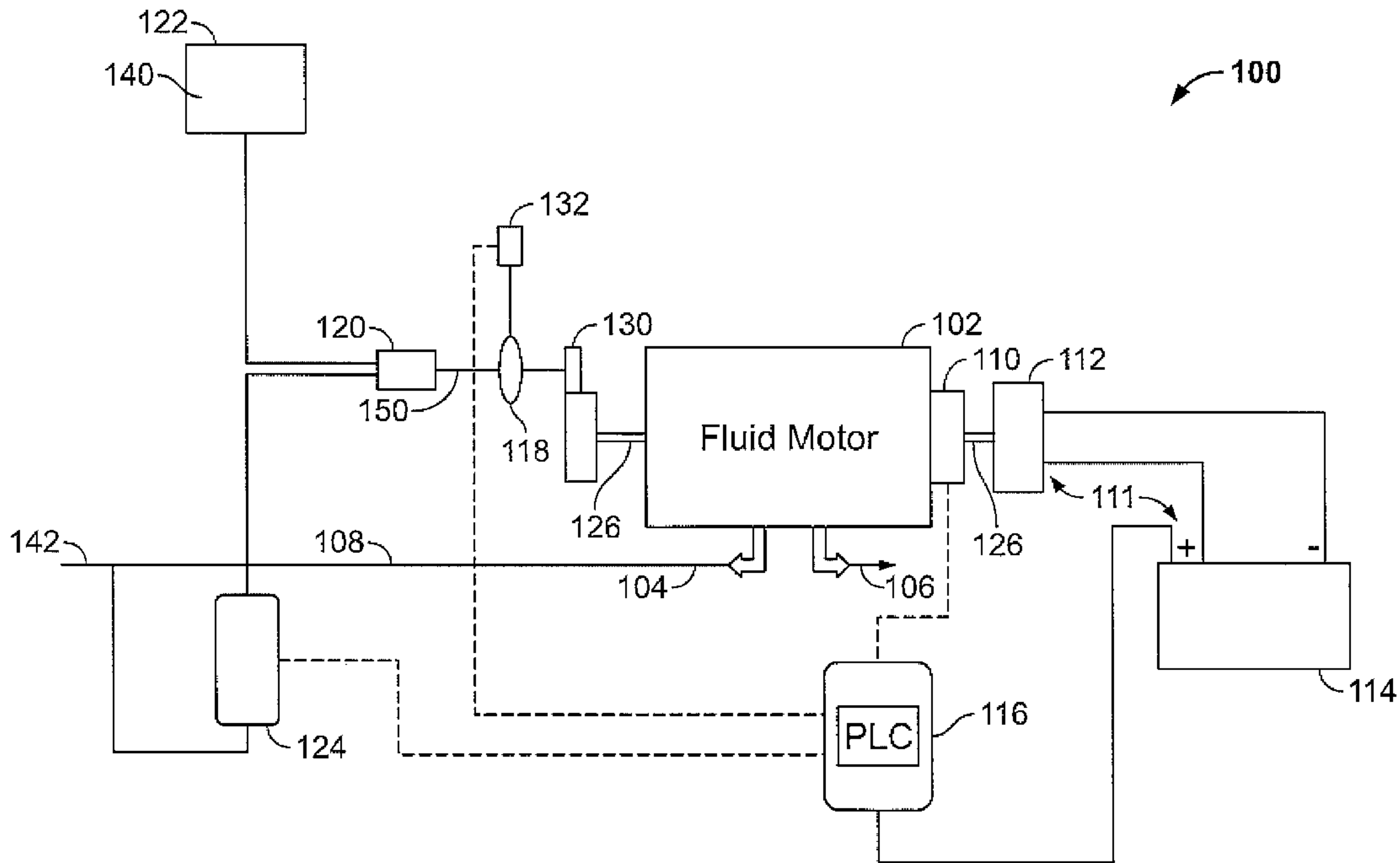


FIG. 1