US 20140147288A1

(19) **United States**

(12) **Patent Application Publication**

Maguire

(10) **Pub. No.: US 2014/0147288 A1**

(43) **Pub. Date: May 29, 2014**

(54) **PUMP ACTUATOR AND METHOD FOR PUMP OPERATION**

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(21) Appl. No.: **14/168,731**

(22) Filed: **Jan. 30, 2014**

Related U.S. Application Data

(63) Continuation-in-part of application No. 13/913,375, filed on Jun. 7, 2013.

(60) Provisional application No. 61/660,326, filed on Jun. 15, 2012.

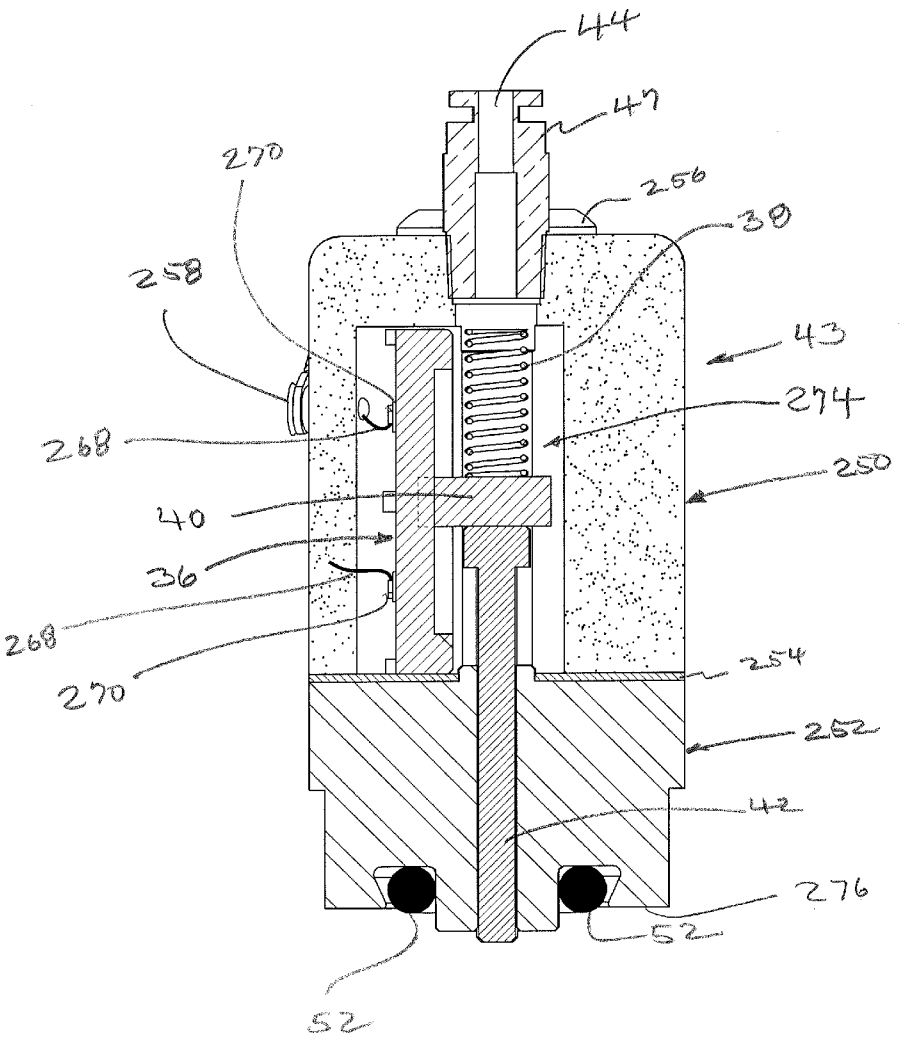
Publication Classification

(51) **Int. Cl.**
F04B 43/02 (2006.01)

(52) **U.S. Cl.**
CPC ***F04B 43/02*** (2013.01)
USPC **417/15**; 92/172

(57) **ABSTRACT**

Method and apparatus for controlling a moveable pumping diaphragm and a liquid color diaphragm pump, including a housing, a movable pin slidably residing within the housing, a potentiometer connected to and residing within the housing for sensing movement of the pin, riding against the diaphragm of the pump and a spring for biasing the pin against the diaphragm.



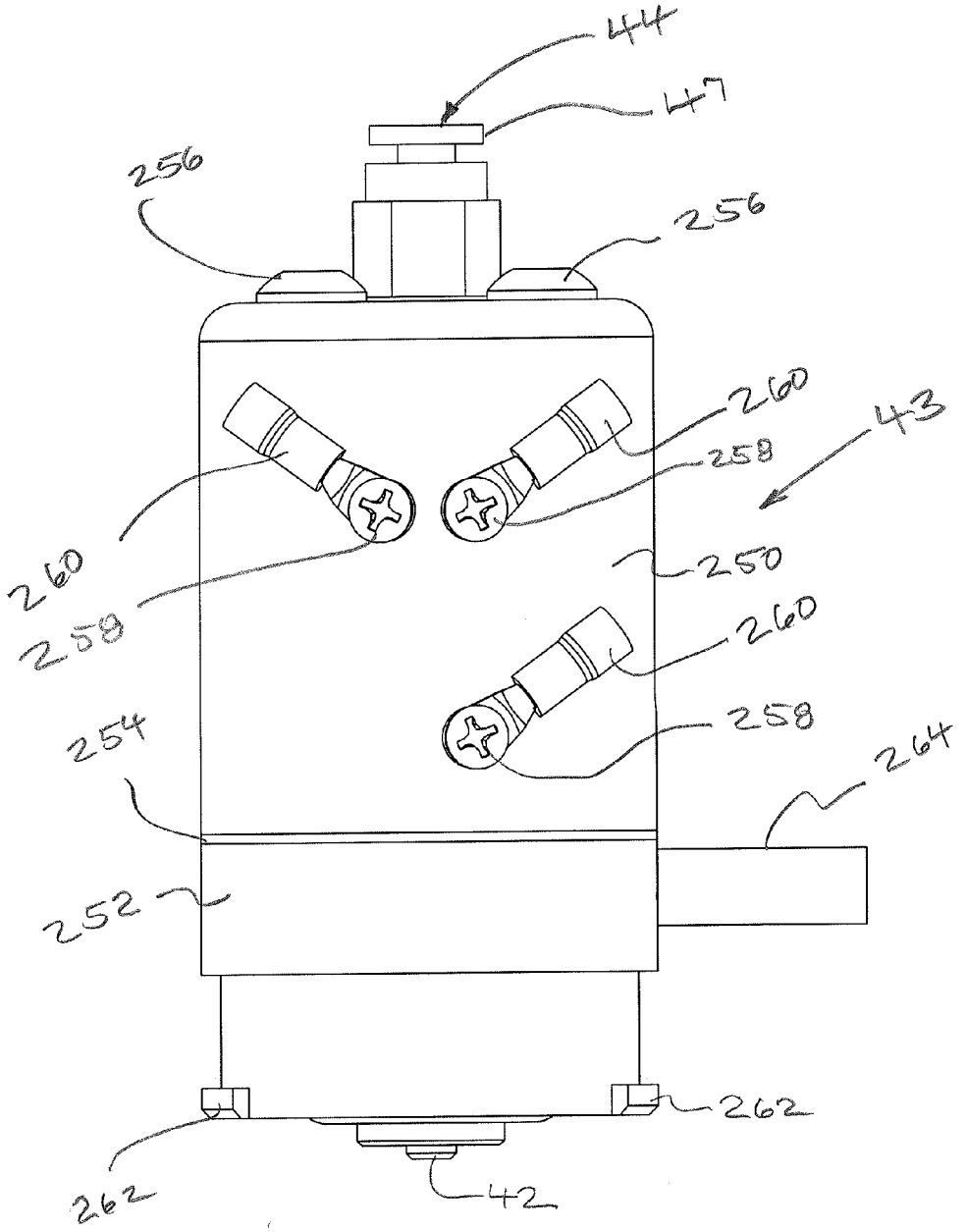

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Figure 1

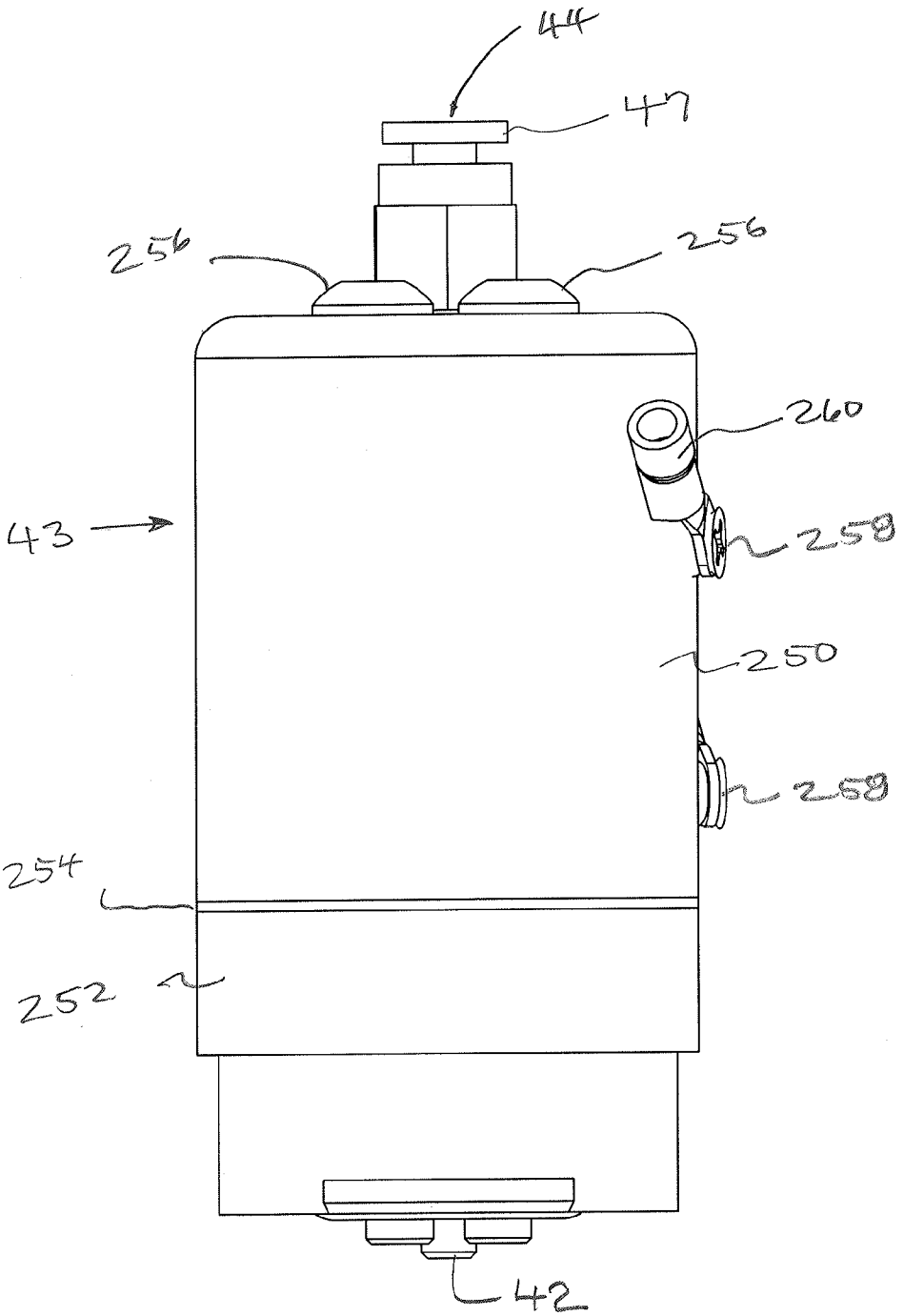


FIGURE 2

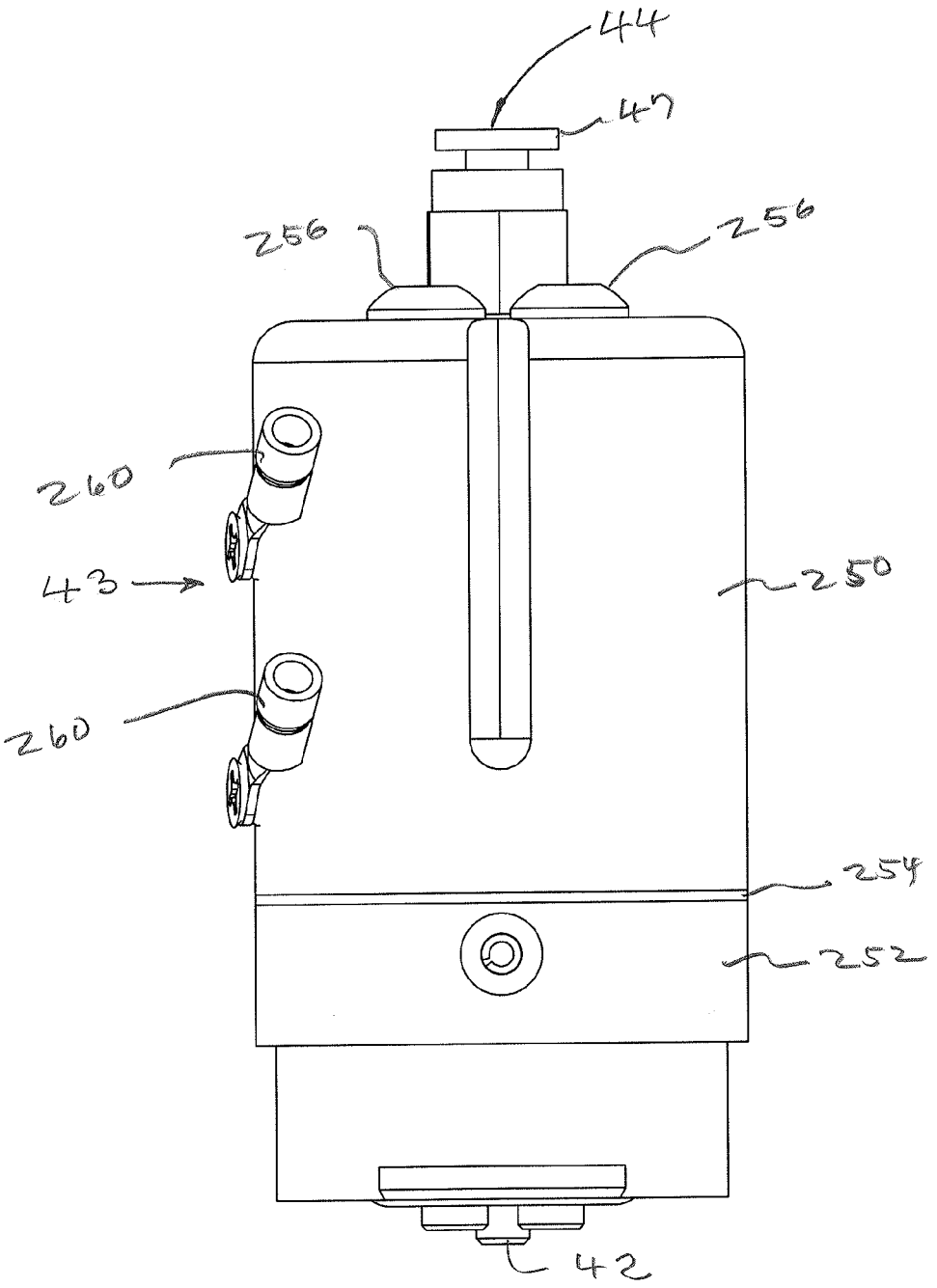


FIGURE 3

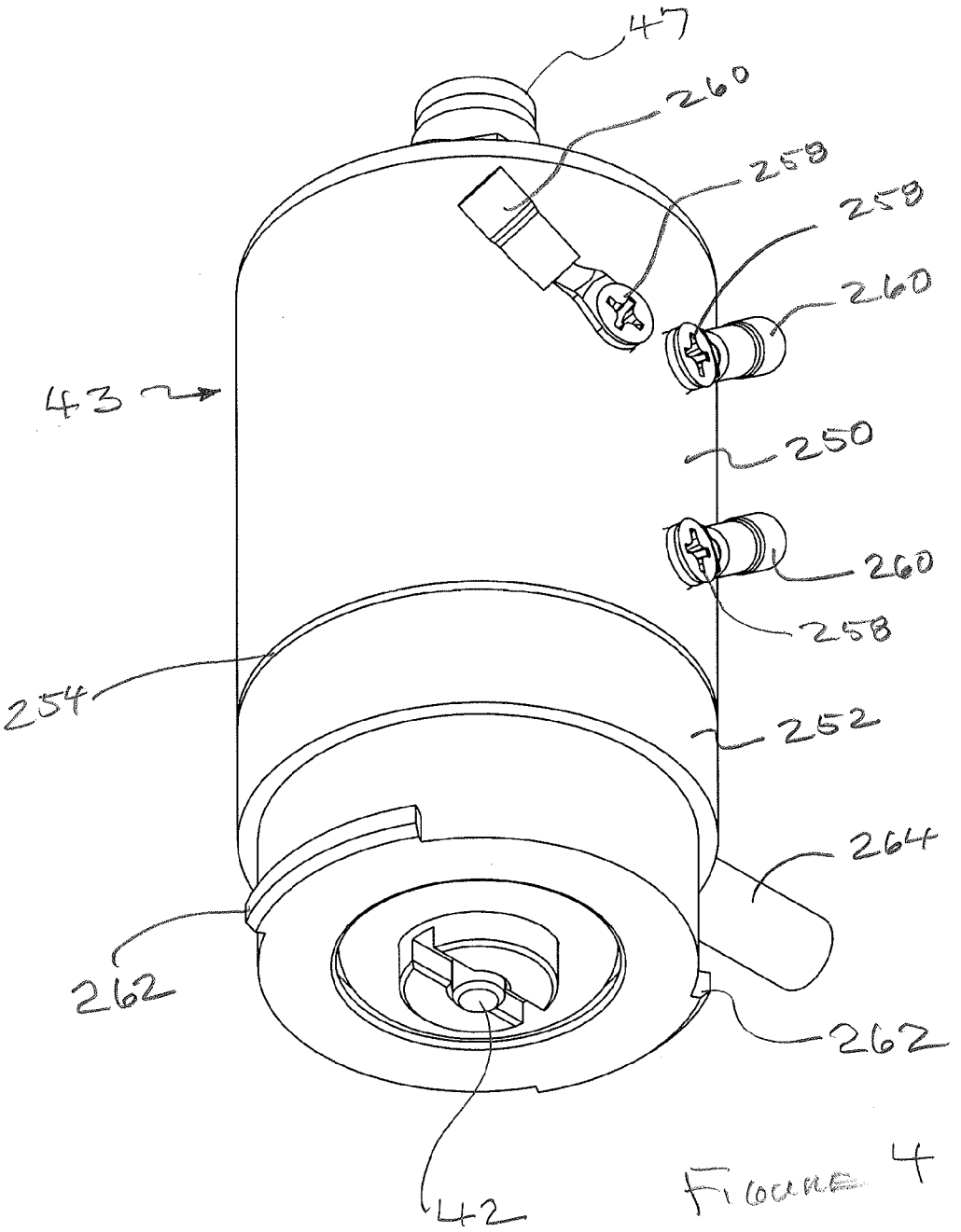


Figure 4

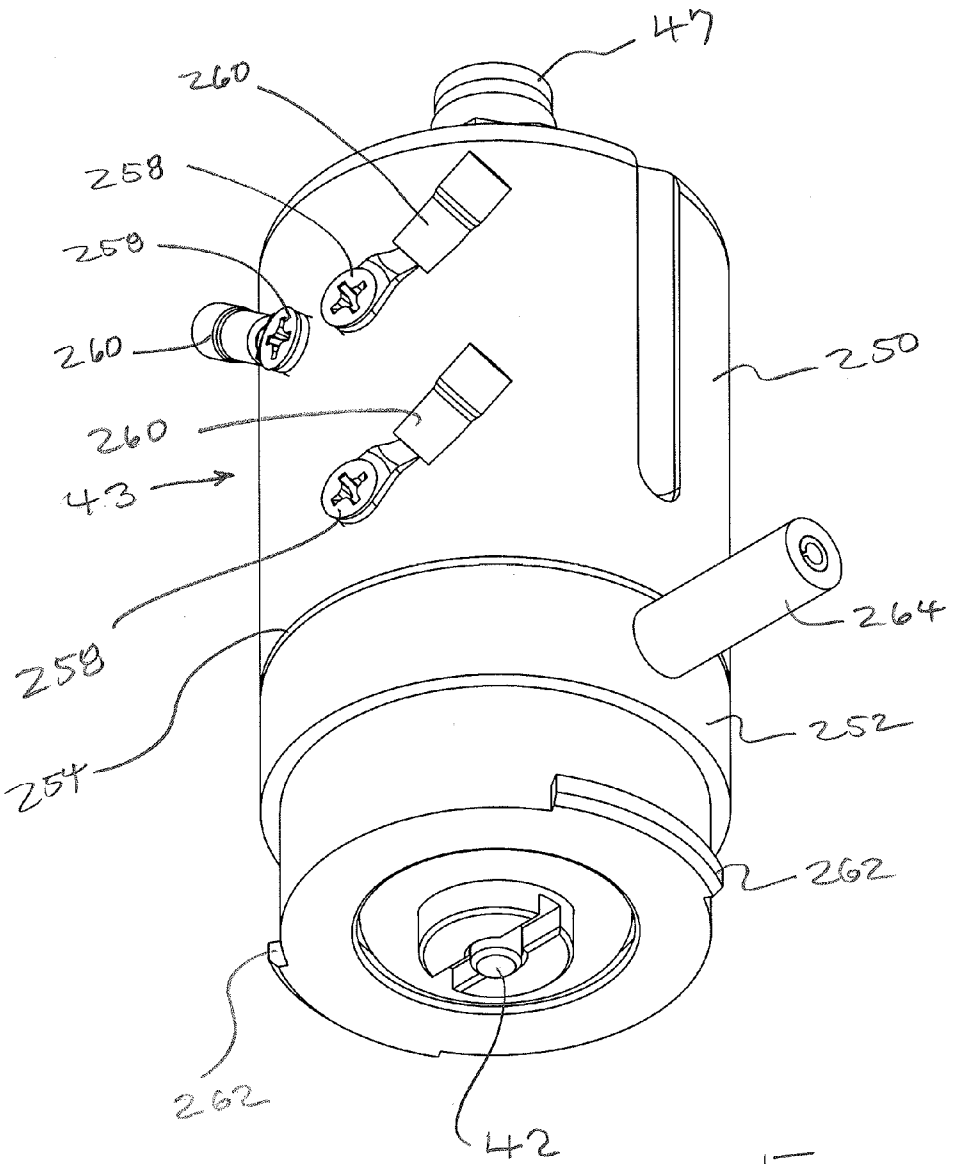


FIGURE 5

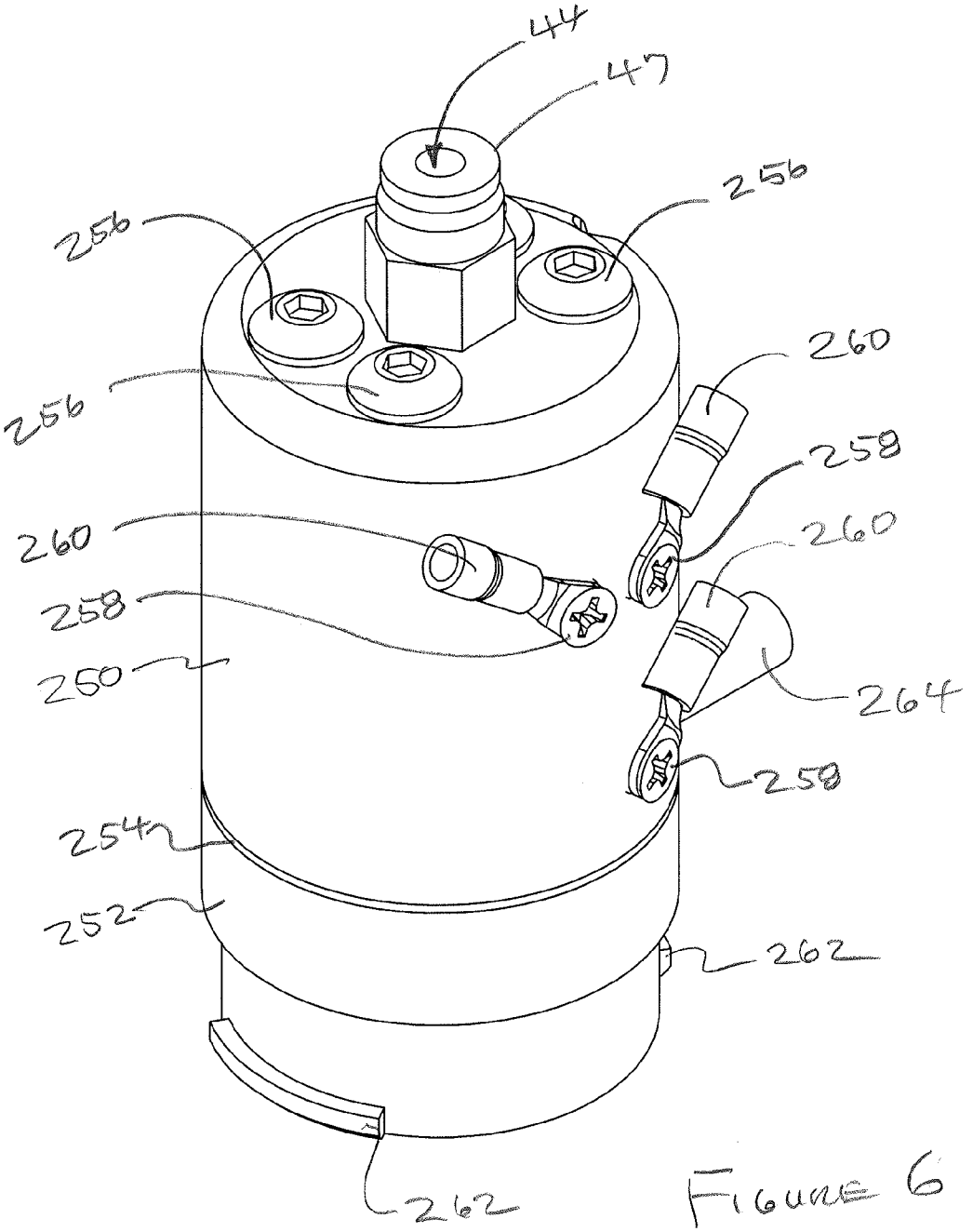


FIGURE 6

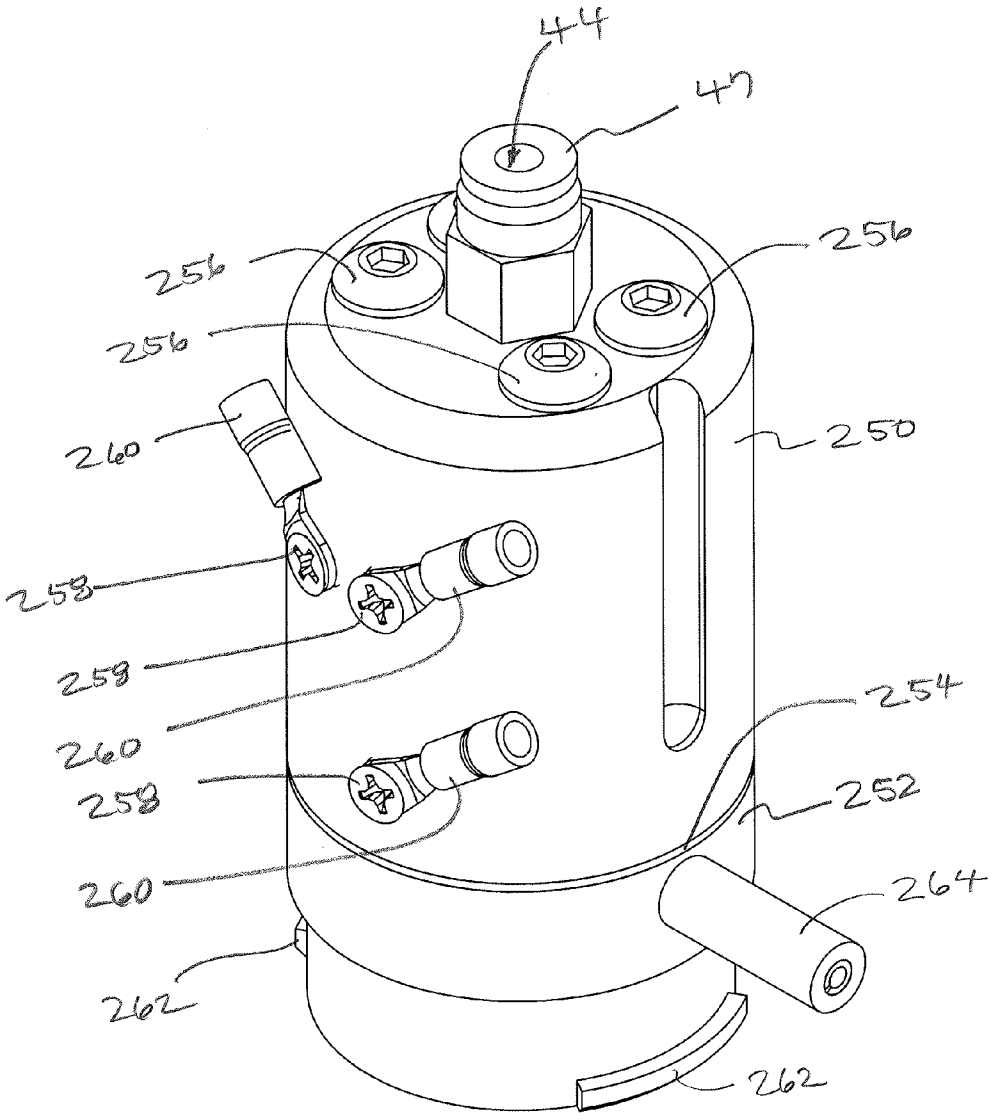


FIGURE 7

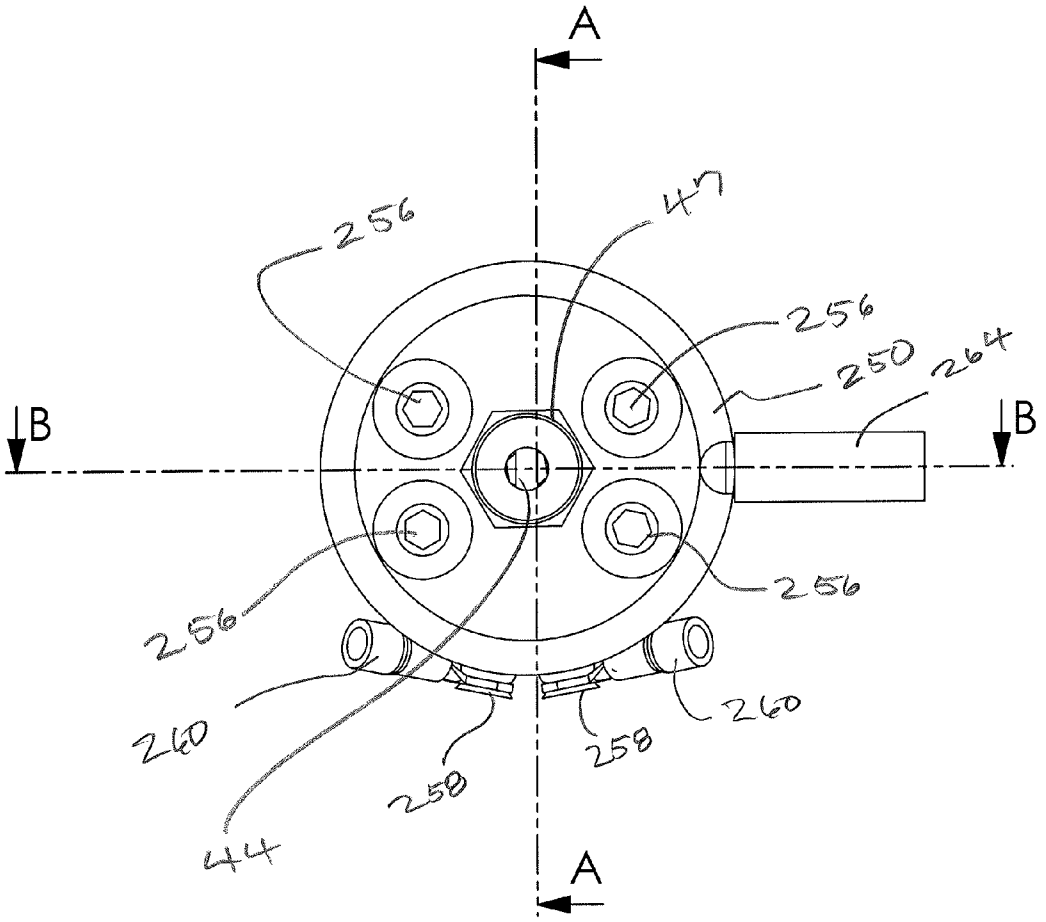
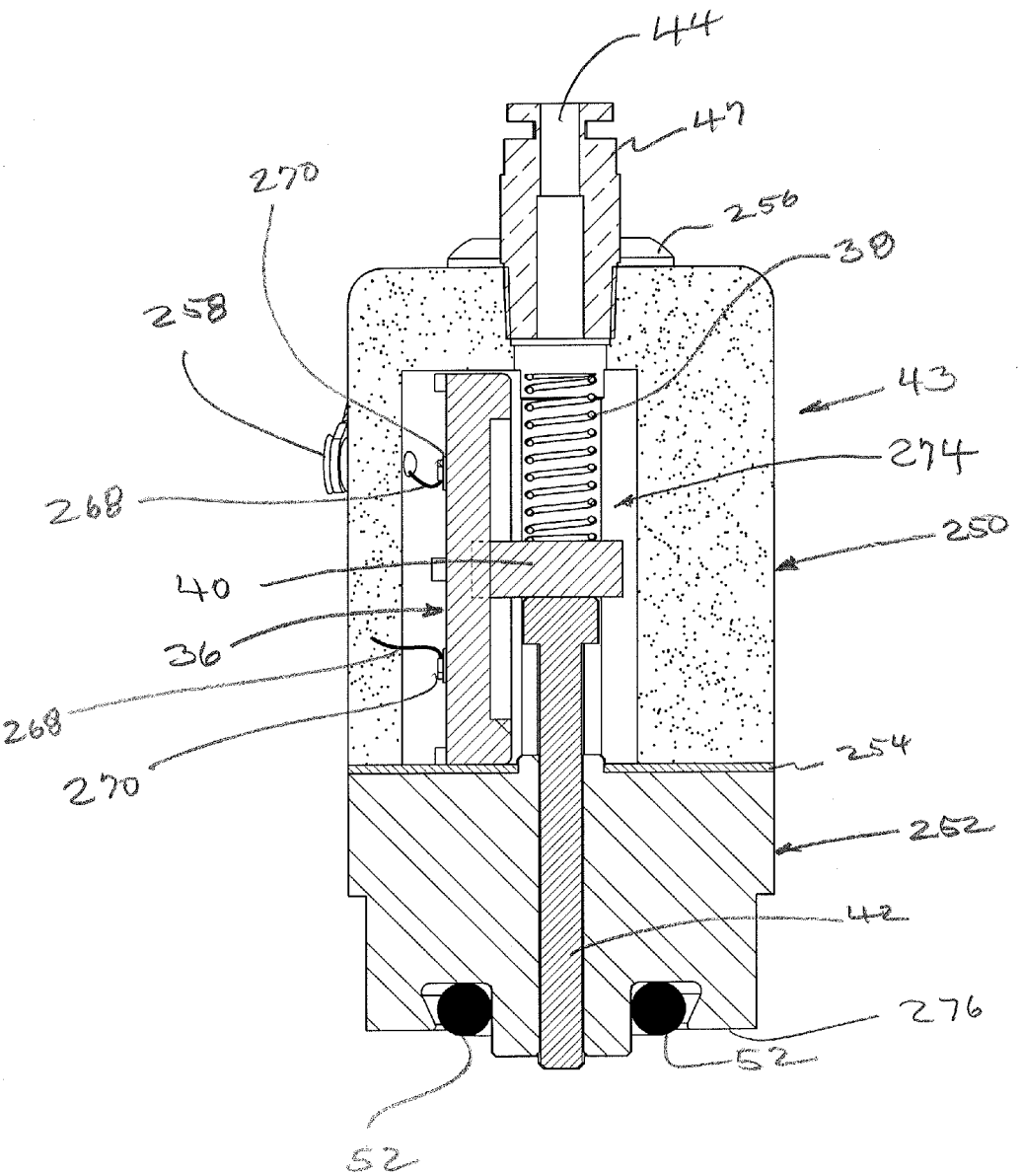


Figure 8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250
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262
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52

Figure 9

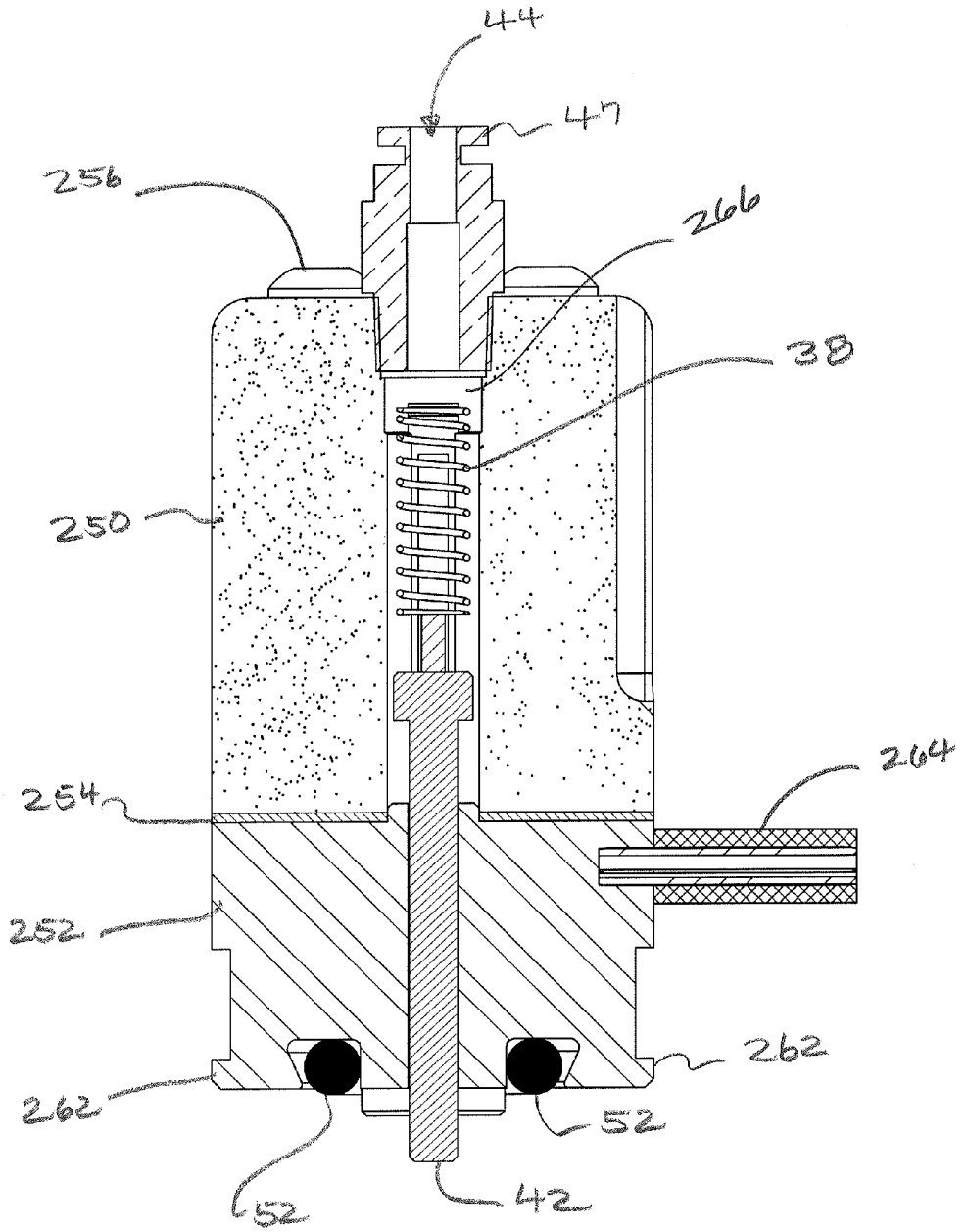

Figure 10

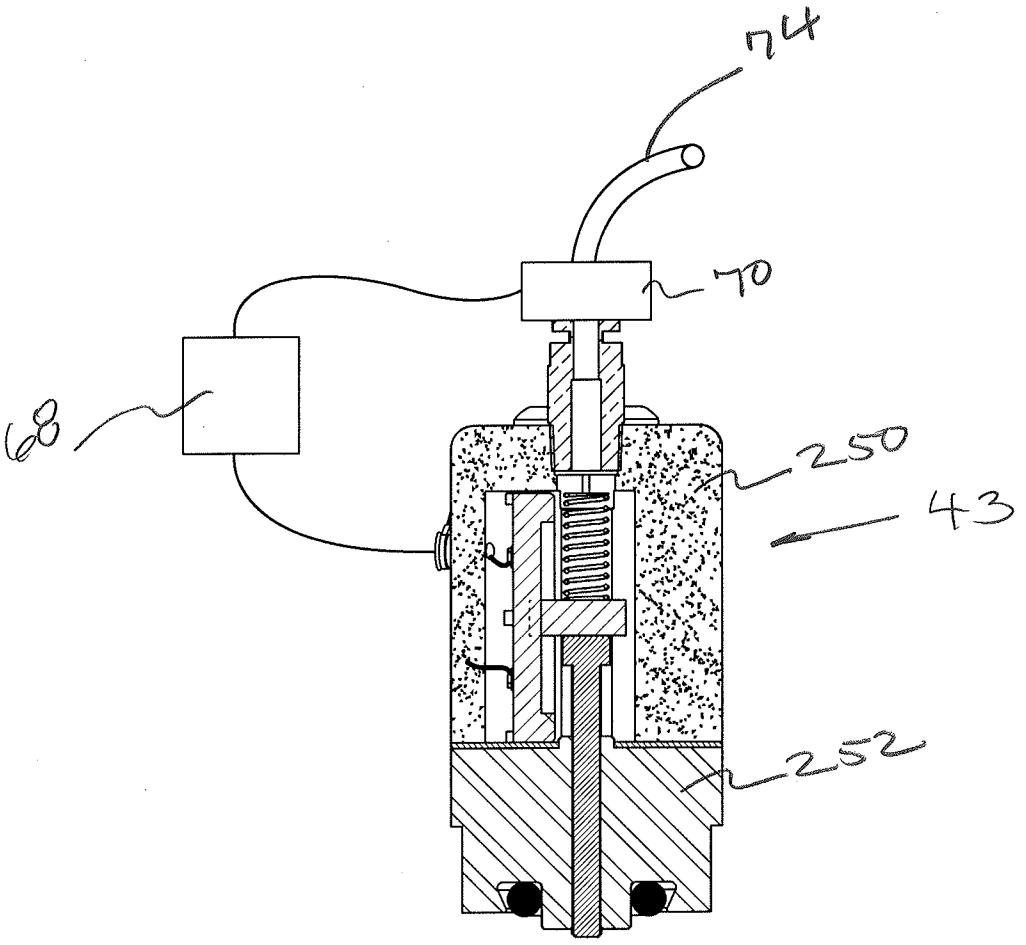

Figure 11

PUMP ACTUATOR AND METHOD FOR PUMP OPERATION

CROSS-REFERENCE TO RELATED PATENT APPLICATION

[0001] This patent application is a continuation-in-part of U.S. patent application Ser. No. 13/913,375 filed 7 Jun. 2013 in the name of Stephen B. Maguire and published as U.S. 2013/0334258 A1, the priority of which is claimed under 35 USC 120. The '375 application claims the benefit of the priority under 35 USC 119 and 35 USC 120 of provisional U.S. patent application Ser. No. 61/660,326 filed 15 Jun. 2012 in the name of Stephen B. Maguire and entitled "Molded Diaphragm Pump." The instant application similarly claims the benefit of the priority of the '**326** application through the parent '375 application noted above. The disclosures of both of these preceding applications are hereby incorporated by reference in their entireties.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention pertains to pumps and more specifically to diaphragm and piston pumps used to pump liquid color. The patent application even more specifically pertains to a device used to actuate the pumping action of a liquid color diaphragm pump. The liquid color diaphragm pump is preferably, but not necessarily, a liquid color pump installed on the lid of a liquid color container. Most preferably the liquid color pump is an integral part of the lid of a drum of liquid color container.

[0004] 2. Description of the Prior Art

[0005] Diaphragm pumps and piston pumps are known. In both diaphragm pumps and piston pumps, the pump provides a reciprocating action whereby the pump alternately displaces liquid and then pulls in additional liquid to be pumped from a pumping chamber. All such pumps involved two check valves. An inlet check valve allows liquid to enter the pumping chamber, but prevents liquid from exiting back out of the pumping chamber through the inlet check valve. An outlet check valve allows the pumped liquid to exit the pumping chamber and prevents the liquid from returning to the pumping chamber through the outlet check valve.

[0006] In a diaphragm pump, the moving diaphragm serves to suck liquid through the inlet into the pumping chamber and then pumps the liquid by applying pressure to the liquid to force the liquid out of the pumping chamber via the liquid outlet.

SUMMARY OF THE INVENTION

[0007] In one of its aspects, this invention provides a method for operating a pump having a moveable pumping member within a pumping chamber, where the method preferably includes positioning a moveable reciprocable member in contact with a pumping member to move reciprocally in concert with the pumping member. In this aspect, the invention preferably proceeds with sensing position of the reciprocable member, which is indicative of the position of the pumping member, and producing a signal indicative thereof. The method then preferably proceeds in this aspect by periodically applying force to the pumping member to move the pumping member and thereby effectuate pumping of liquid from the chamber. The method preferably further involves using the signals to regulate frequency of force application to the pumping member to achieve a preselected rate of output from the pump.

[0008] In one application of the actuator of the invention, addition of color to a plastic molding or processing operation requires careful metering, which this invention provides. When such color is added, the rate of color dispensing must exactly match the rate requirement of the process machine. Consequently, speed of the liquid color pumping process must be carefully controlled. In the instant invention, rate of pumping is controlled and even partial pumping strokes may be effectuated by the invention preferably pulsing very small bursts of air into the liquid color pump above the diaphragm portion of the pump. By regulating the duration of each air pulse and regulating the time between air pulses, the invention facilitates metering liquid color at a desired precisely controlled flow rate.

[0009] The actuator of the invention preferably provides continuous feedback of the exact position of a liquid color pump diaphragm at all times as air pushes the diaphragm downward during the pumping stroke. Such continuous feedback information regarding the exact position of the diaphragm at all times preferably allows continuous monitoring and correction of liquid color flow rate by regulation of the frequency and duration of the air pulses applied to the diaphragm and also preferably facilitates accurate, partial strokes of the pumping diaphragm. The invention accomplishes this by preferably providing a moveable pin that follows the diaphragm of the liquid color pump as the diaphragm moves down and up. The invention further accomplishes this by using a linear potentiometer in a position so that the potentiometer is within the actuator and senses movement of the pin.

[0010] In a typical application, total movement of the diaphragm portion of the liquid color pump is preferably about one-quarter of one inch. The preferred slide potentiometer portion of the actuator of the invention is preferably capable of about 20 millimeters, or about three-quarters of an inch, of movement of the sensing slide of the potentiometer. In the course of practice of the invention, the upper and lower limits of potentiometer movement are preferably recorded using a microprocessor and readings in between these upper and lower limits are preferably used to calibrate the actuator to determine the precise location of the pin and hence of the diaphragm as the diaphragm moves up and down and pumps the liquid color.

[0011] In the most preferred operation of the invention, the invention utilizes only about one-quarter inch of the diaphragm movement, which translates into about 300 different position readings of the moveable potentiometer arm, and hence the position of the pin riding the diaphragm, and the position of the diaphragm itself, thereby assuring precise location information at all times respecting the position of the pumping diaphragm.

[0012] In the preferred manifestation of the invention, the potentiometer preferably is entirely within a chamber interior of the actuator, which chamber is pressurized. Electrical signals from the potentiometer are brought out of the actuator and out of the pressurized chamber within the actuator preferably via screws that make contact with the potentiometer connections inside the actuator that are themselves sealed against air leakage where they enter the actuator body. The absence of any moving, sliding seals assures correct opera-

tion of the potentiometer and actuator for many years with there being no wear points to fail.

[0013] A light spring, above the slide arm of the potentiometer and biasing the actuator pin downwardly, assures that the potentiometer slide arm or "T-bar" and the actuator pin follow the diaphragm downwardly as air pushes the diaphragm down.

[0014] The actuator is removable from the pump using a one-quarter turn locking system with an O-ring base. This allows the actuator to be installed or removed easily and frequently, while effectively sealing the actuator against the pump surface whenever the actuator is installed.

[0015] The method aspect of the invention may preferably further include recording signals at the extremities of actuator pin travel, using those signals and the known length of actuator pin travel to determine location of the actuator pin based on signal received at a given time and adjusting the frequency of application of force to the pumping diaphragm according to the location of the actuator pin and the potentiometer slide arm or T-bar, to maintain the desired output from the pump.

[0016] The method may further involve using the signals and known length of the actuator pin travel to determine location of the actuator pin based on signal received at a given time and may further include determining the relationship between the duration of force application to the pumping diaphragm and the pumping diaphragm displacement.

[0017] In another one of its aspects, this invention provide apparatus for controlling a moveable pumping member and a pump, where the apparatus includes a housing, a reciprocally moveable pin slidably residing within the housing, and having an extremity portion passing through the housing for contacting the moveable pumping diaphragm and moving unitarily with the moving pumping diaphragm. The apparatus aspect of the invention further preferably includes a potentiometer connected to and residing within the housing for sensing movement of the pin and producing a signal indicative thereof, and spring for biasing the pin against the pumping member. A microprocessor is also included, as is a solenoid valve, for regulating air bursts applied to the diaphragm to facilitate pumping.

[0018] In the apparatus aspect of the invention, the housing may have a first aperture for connection to a supply of pulsed air, where the housing is otherwise sealed and air tight except optimally for passage of air along the pin where the pin passes through the housing.

[0019] In the apparatus aspect of the invention, the potentiometer desirably has a moveable slide arm or T-bar portion positioned between and contacting both the light upper spring and the pin. In the apparatus aspect of the invention, the actuator housing is preferably at least partially polymer foam. In the apparatus aspect of the invention, the signals are desirably electrical signals and the potentiometer desirably has terminals providing the electrical signals indicative of movement of the pin. In such aspect of the invention, the apparatus further comprises signal carriers electrically connected to terminals in passing through the housing, and electrical connectors mounted on the housing exterior and being electrically connected to the signal carriers, for connection to the microprocessor, to in turn activate the solenoid valve to apply bursts of pumping air to the diaphragm. In the apparatus aspect of the invention, the pumping member is desirably a diaphragm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1** is a front elevation of an actuator embodying aspects of the invention.

[0021] FIG. **2** is a left side elevation of the actuator illustrated in FIG. **1**.

[0022] FIG. **3** is a right side elevation of the right side actuator illustrated in FIGS. **1** and **2**.

[0023] FIG. **4** is an isometric view of the actuator illustrated in FIGS. **1** through **3** showing the bottom of the actuator and the left quarter of the actuator, namely the side portion of the actuator shown partially in FIG. **1** and partially in FIG. **2**.

[0024] FIG. **5** is an isometric view of the actuator illustrated in FIGS. **1** through **4** showing the right quarter of the actuator, namely the side portion of the actuator illustrated in FIGS. **1** and partially in FIG. **3**.

[0025] FIG. **6** is an isometric view of the actuator showing the top of the actuator and the front left quarter side portion illustrated in FIG. **4**.

[0026] FIG. **7** is an isometric view of the actuator showing the top of the actuator and the front right quarter side portion illustrated in FIG. **5**.

[0027] FIG. **8** is a top view of the actuator illustrated in FIGS. **1** through **7**.

[0028] FIG. **9** is a sectional view of the actuator illustrated in FIGS. **1** through **8**, with the section taken at lines and arrows A-A in FIG. **8**.

[0029] FIG. **10** is a sectional view of the actuator illustrated in FIGS. **1** through **9**, with the section taken at lines and arrows B-B in FIG. **8**.

[0030] FIG. **11** is a schematic view, partially in section, showing the actuator illustrated in FIGS. **1** through **10** together with a connected microprocessor and a connected solenoid valve.

DESCRIPTION OF THE PREFERRED EMBODIMENTS AND BEST MODE KNOWN FOR PRACTICE OF THE INVENTION

[0031] The actuator **43** of this invention has specific applicably to liquid color diaphragm pumps; the actuator may also be used with piston-type pumps.

[0032] In a pump to which the actuator is best adapted for use, such as that disclosed in pending U.S. Ser. No. 13/913,375, air is applied to the top side of the diaphragm, to press the diaphragm down. This downward movement of the diaphragm defines the "pumping stoke". In the pump, a spring on the bottom side of the diaphragm acts against the diaphragm to move the diaphragm up. Upward movement of the diaphragm in response to the spring pressure defines the "suction stroke".

[0033] In the preferred pump, normally the diaphragm is operated in full strokes, moving through the full range of motion for which the diaphragm is designed in the pump. Moving the diaphragm downward through the full range of motion is preferably accomplished by opening a solenoid actuated air valve **70** and applying air pressure to move the diaphragm preferably all the way to the bottom of its range of motion, which may be to the bottom of the pumping cavity.

[0034] When liquid color is used to color plastic parts during fabrication, careful metering of liquid color consumption is required as the liquid color is added while the plastic resin is melted and processed by a process machine. The rate the

liquid color is dispensed by the pump must exactly match the rate at which the liquid color is consumed by the process machine.

[0035] The rate or speed of the liquid color pumping process must be precisely controlled. In some applications only require partial pump strokes are required. The rate at which liquid color is supplied by the pump is controlled by carefully pulsing only very small bursts of air into the pump, into the space above the diaphragm. Regulating the duration of each air pulse and regulating the time between pulses results in metering the liquid color to the process machine at exactly the desired flow rate so that the process machine receives precisely the amount of liquid color the process requires, at exactly the right rate of supply of liquid color.

[0036] Critical to the success of this process for supplying liquid color is having continuous feedback of the exact position of the diaphragm at all times as compressed air released by solenoid valve **70** pushes the diaphragm downward. Knowing the exact position of the diaphragm at all times allows accurate continuous monitoring and correction of the liquid color flow rate by regulation of the solenoid valve by the potentiometer and microprocessor, and also allows accurate metering of partial stokes of the diaphragm.

[0037] The actuator of this invention accomplishes this by providing a pin **42** that lightly rides the surface of the diaphragm, following the diaphragm as the diaphragm moves down and up. The actuator **43** of this invention further involves positioning a potentiometer **36**, most desirably a linear potentiometer, so that potentiometer **36** is actuated by movement of pin **42**. In one preferred embodiment, total diaphragm movement in the invention may be about 0.25 inch. The potentiometer arm **40** and pin **42** may move about 0.75 inch or more, but in the preferred embodiment, the invention typically uses only 0.25 inch of that stroke.

[0038] Initially, a microprocessor **68** records the upper and lower extreme positions of the linear potentiometer slider arm **40**, corresponding to the upper and lower limits of diaphragm travel. The microprocessor **68** then uses the readings of the potentiometer slider arm **40** that are between the corresponding upper and lower limits of diaphragm travel to determine the exact location of the diaphragm as the diaphragm moves up and down and pumps liquid color. The 0.25 inch of stroke of the diaphragm translates into about 300 different position readings of the pin **42** and potentiometer slider arm **40**, which may be stored and used by the microprocessor, assuring precise readout of diaphragm location at any time.

[0039] The invention provides pin **42** for physical connection of potentiometer **36** with the top side of a diaphragm. This is to sense the movement of the diaphragm. Using a moving pin passing through an air pressure seal would risk leaking air around the seal. Any such air leak, even the slightest air leak, would compromise metering accuracy.

[0040] The invention has no parts moving through a seal. The potentiometer and pin are enclosed entirely within an actuator internal chamber **274** that is pressurized.

[0041] Electrical signals from the potentiometer are brought out of the pressurized volume of actuator internal chamber **274** through screws **257** making contact with potentiometer electrical leads **268**, which in turn connect with the potentiometer electrical leads **270** inside the pressurized volume; the screws themselves are sealed against air leakage where they enter the pressurized chamber. Absence of any moving or sliding seals assures correct operation for many years with no wear points to fail.

[0042] A light spring **38**, above slide portion **40** of potentiometer **36** and bearing on pin **42**, assures that pin **42** follows the diaphragm down as the air pushes the diaphragm down. Preferably a heavy pump spring, inside a preferred pump, pushes the diaphragm up at the end of a pump stoke, and the diaphragm then pushes pin **42** and potentiometer slide portion **40** up against the bias of light spring **38**.

[0043] The actuator **43** is removable from the pump. Preferably a one-quarter turn locking system with an O-ring base seal allows the actuator to be installed or removed easily while effectively sealing against the pump surface.

[0044] In the drawings it can be seen that that actuator **43** is generally cylindrical in form, with an air inlet **44** at the top thereof being fed by an air supply line **45**, which supplies air indirectly with the air being controlled by solenoid valve **70** preferably operating off of a house air line **74**. A microprocessor **68** receives signals from the slide potentiometer designated generally **36** which is resident within actuator **43**. Also resident within actuator **43** is light biasing spring **38** which works to bias actuator pin **42** and intervening T-bar portion **40** of slide potentiometer **36** downwardly. This downward bias of actuator pin **42** assures that the end of actuator pin **42** is always riding on the diaphragm of a pump being controlled by actuator **40**.

[0045] The diaphragm of the pump does the actual pumping. Spring **38**, slide potentiometer **36** and actuator pin **42** monitor the position of the diaphragm in the pumping chamber as the diaphragm moves in response to air pressure, most desirably bursts of air pressure, applied to the top side of the diaphragm as air passes downwardly around the edges of actuator pin **42**, as the air is released by intermittent operation of solenoid valve **70** when triggered by microprocessor **68**. The air maintains a pressurized condition within actuator internal chamber **274**.

[0046] Actuator **43** has an upper portion **250** and a lower portion **252** which are connected and held together by hold down bolts **256**. An actuator internal gasket **254** resides between actuator upper portion **250** and actuator lower portion **252**.

[0047] Actuator upper portion **250**, within which actuator chamber **274** is located, is preferably insulative, air tight polymer foam.

[0048] Actuator **43** further includes actuator signal connection external terminals designated **258** in the drawings which have associated therewith tubular connection covers **260**, so that suitable wire connections can be made to actuator signal connection external terminals **258**, with the wire connections desirably passing through tubular connection covers **260**.

[0049] Actuator **43** further includes a pair of lugs **262** which form the male potion of a preferable quarter turn quick disconnect assembly which allows actuator **43** to be quickly removed from the liquid color pump and replaced if need be. A handle **264** is provided as part of actuator **43** to assist in manual, preferably quarter turn, rotational movement of actuator **43** to remove it from the liquid color pump.

[0050] An abutment plug is provided at the top of pin biasing spring **38**, as illustrated in FIG. **11**, with a tiny passageway optionally being provided through abutment plug **266** to facilitate air passage from the solenoid valve downwardly through actuator **43** into contact with the upper service of a diaphragm portion of a liquid color pump to which actuator **43** is connected. Alternatively, air from solenoid valve **70** may pass around the sides of a solid abutment plug **266**, between

abutment plug **266** and the annular interior surface of actuator upper portion **250**, to reach the pumping diaphragm.

[0051] Electrical leads from slide potentiometer **36** that are internal to actuator **43** are designated generally **268**. These leads extend from potentiometer electrical terminals **270** that are shown in FIG. **11**. An actuator chamber **274** is present within upper portion **250** of actuator **43** with slide potentiometer **36**, pin biasing spring **38**, and the upper portion of actuator pin **42** all being resident therewithin, as illustrated in FIGS. **10** and **11**. The actuator chamber **274** present within upper portion **250** of actuator **43** houses slide potentiometer **36**, pin biasing spring **38** and the upper portion of actuator pin **42**. Upon microprocessor **68** actuating solenoid valve **70** to provide a pulse of air via air inlet **44**, the air passes downwardly through inlet **44** into actuator chamber **274** and around and between pin **42** and the surrounding lower portion **252** of actuator **43** to escape at the bottom of pin **42** into the pumping chamber where the air is on the upper side of the pumping diaphragm of the diaphragm pump.

[0052] O-rings **52** are provided so that in combination with the quarter turn release mechanism of which lugs **262** are a part, the actuator upon a quarter turn thereof is in tight facing connection with the frame portion of the associated pump such that an air tight seal is created between the lower planar surface **276** of actuator lower portion **252** and the pumping chamber in which the diaphragm resides. Once the air applied to the diaphragm has pushed the diaphragm downwardly, thereby forcing liquid color below the diaphragm out through the outlet portion of the associated pump, a strong spring also located in the associated pump pushes the diaphragm upwardly, back into the neutral position, whereupon another pulse of air, signaled by the microprocessor and released by action of the solenoid valve, passes downwardly through actuator chamber **274** as described above and applies force in the form of air pressure to the upper side of the pumping diaphragm.

[0053] Actuator chamber **274** is sealed such that air cannot enter actuator chamber **274** other than through the action of microprocessor actuating the solenoid valve and providing air in pulses via air inlet **44**. All electrical connections to potentiometer **36** are provided by potentiometer electrical leads **268**, typical ones of which have been illustrated in the drawings. These potentiometer electrical leads pass through the polymer foam body of actuator upper portion **250** and are sealed within that polymer foam body so that no air can enter into actuator chamber **274** other than the air provided by solenoid valve **70**.

[0054] While the actuator of the invention has been illustrated in generally cylindrical form, the actuator may be in any other form such as with a triangular horizontal cross-section, a rectangular horizontal cross-section, a hexagonal horizontal cross-section, and an octagonal horizontal cross-section, etc.

[0055] Gasket **254** provides a tight seal between the upper portion **250** and lower portion **252** of actuator **43**. The presence of air pressure within actuator chamber **274** assures that air will not flow into chamber **274** other than through air inlet **44** as air provided by inlet **44** is on its way to the top surface of the pumping diaphragm.

1) A method for operating a pump having a movable pumping member and a pumping chamber, comprising:

a) positioning a movable reciprocable member in contact with the pumping member to move reciprocally in concert with the pumping member;

b) sensing position of the reciprocable member and producing signals indicative thereof;

c) periodically applying force to the pumping member to move the pumping member and thereby effectuate pumping of fluid from the chamber;

d) using the signals to regulate frequency of force application to the pumping member to achieve a preselected rate of output from the pump.

2) The method of claim **1** further comprising:

a) recording the signals at the extremities of reciprocable member travel;

b) using those signals and known length of reciprocable member travel to determine location of the reciproable member based on signal received at a given time;

c) adjusting the frequency of application of force to the pumping member according to the location of the reciprocable member to maintain a desired output from the pump.

3) The method of claim **2** wherein the step of using those signals and known length of reciprocable member travel to determine location of the reciproable member based on signal received at a given time further includes determining the relationship between duration of force application to the pumping member and pumping member displacement.

4) The method of claim **1** wherein the pumping member is a diaphragm.

5) The method of claim **1** wherein the sensing is performed by a potentiometer.

6) The method of claim **1** wherein the force is pneumatically applied.

7) The method of claim **1** wherein the pumping chamber is air-tight.

8) The method of claim **5** wherein the potentiometer is within an actuator chamber.

9) The method of claim **8** wherein the actuator chamber is sealed.

10) The method of claim **9** wherein the actuator chamber is within polymer foam.

11) The method of claim **1** further comprising adjusting the frequency of application of force to the pumping member according to the location of the reciprocable member to maintain a desired output from the pump.

12) The method of claim **2** wherein the force is applied to the pumping member by bursts of air.

13) The method of claim **1** further comprising the steps of:

a) noting position of the reciprocable member as indicated by a potentiometer signal;

b) applying a burst of air to the pumping member;

c) recording a second potentiometer signal indicative of reciprocable member position; and

d) determining pumping member movement as a function of applied force duration from the movement of the reciprocable member in response to the air burst applied to the pumping member.

14) The method of claim **1** wherein periodically applying force to the pumping member to move the pumping member and thereby effectuate pumping of fluid from the chamber is performed by controlling duration and timing of air bursts applied to the pumping member.

15) A method for operating a liquid color diaphragm pump, comprising controlling duration and sequencing of bursts of air applied to a diaphragm contacting the liquid color being pumped.

16) A method for operating a liquid color pump having a movable pumping member and a sealed pumping chamber, comprising:

a) positioning a movable reciprocable member within an actuator chamber in contact with the pumping member to move reciprocally in concert with the pumping member;

b) sensing position of the reciprocable member within the actuator chamber and producing signals indicative thereof;

c) periodically pneumatic applying force to the movable pumping member to move the pumping member and thereby effectuate pumping of liquid color;

d) using the signals to regulate frequency of pneumatic force application to the pumping member to achieve a desired rate of output from the pump.

17) An actuator for controlling a movable pumping member in a pump, comprising:

a) a housing;

b) a movable pin slidably residing within the housing, having an extremity portion passing through the housing for contacting the movable pumping member and moving unitarily therewith;

c) a potentiometer connected to and residing within the housing for sensing movement of the pin and producing a signal indicative thereof; and

d) a spring for biasing the pin against the pumping member.

18) Apparatus of claim **17** wherein the housing has a first aperture for connection to a supply of pulsed air, wherein the housing has a sealed chamber within the pin, spring and potentiometer reside.

19) Apparatus of claim **17** wherein the potentiometer has a movable portion positioned between and contacting the spring and the pin, for movement with the pin.

20) Apparatus of claim **18** wherein a portion of the housing comprising the chamber is polymer foam.

21) Apparatus of claim **17** wherein the signals are electrical signals, the potentiometer has terminals providing the electrical signals indicative of movement of the pin, and the apparatus further comprises:

a) signal carriers electrically connected to the terminals and passing through housing; and

b) electrical connectors mounted on the housing exterior and being electrically connected to the signal carriers.

22) Apparatus of claim **20** wherein the signals are electrical signals, the potentiometer has terminals providing the electrical signals indicative of movement of the pin, and the apparatus further comprises:

a) signal carriers electrically connected to the terminals and passing through the polymer foam; and

b) electrical connectors mounted on the chamber exterior and being electrically connected to the signal carriers.

23) Apparatus of claim **17** wherein the pumping member is a diaphragm.

24) An actuator for controlling a movable pumping diaphragm in a liquid color diaphragm pump, comprising:

a) a housing;

b) a movable pin slidably residing within the housing, having an extremity portion passing through the housing for contacting the movable pumping member and moving unitarily therewith;

c) a potentiometer connected to and residing within the housing for sensing movement of the pin and producing a signal indicative thereof; and

d) a spring for biasing the pin against the pumping member;

wherein the housing comprises a sealed chamber within which the pin, spring and potentiometer reside; the potentiometer comprises a movable portion positioned between and contacting the spring and the pin for movement with the pin; a portion of the housing comprising the chamber is polymer foam; the potentiometer has terminals providing the signals indicative of pin movement; and further comprising

e) signal carriers electrically connected to the terminals and passing through the polymer foam.

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