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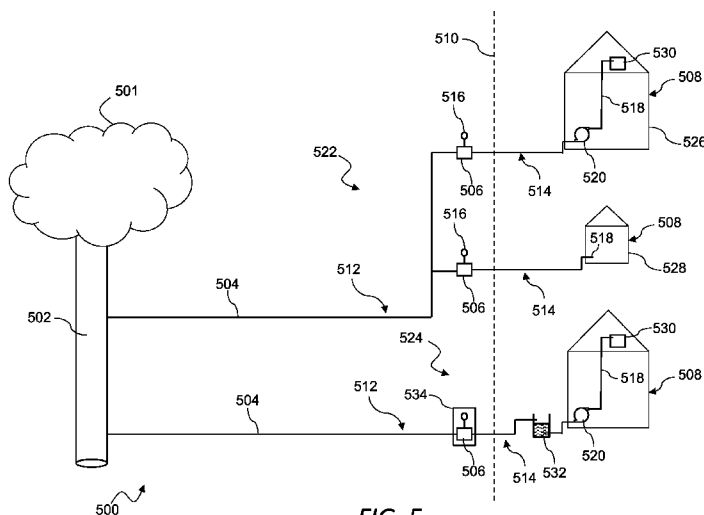


FIG. 5

(57) Abstract: A pressure activated self-throttling valve disposed upstream of a home can mitigate negative pressurization upstream from the valve and its resulting harmful effects on a residential water supply by tending to close when the home imposes a negative pressure on the supply. Specifically, a pinch valve or the like disposed upstream from a home can temper the home's ability to withdraw excess water from a municipality's water supply (e.g., through the use of an inline booster pump or other unauthorized components) and reduce the likelihood of contaminants being drawn into the water supply (e.g., through leaky piping). To this end, the valve may be configured to close when a pressure on the upstream side of the valve falls below a predetermined pressure. Thus, even with a pump operating at the home, when negative pressure is imposed on the supply the valve will tend to close and prevent the home from overdrawing or potentially contaminating the water supply.

SELF-THROTTLING VALVES FOR RESIDENTIAL WATER SUPPLY SYSTEMS

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 61/923,289 filed on January 3, 2014, the entire content of which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] The present disclosure generally relates to self-throttling valves for regulating back-pressure in residential water supply systems.

BACKGROUND

[0003] In aging or poorly constructed residential water distribution systems such as those found in urban neighborhoods throughout the developing world, some individuals address low pressure conditions by using centrifugal pumps or the like—frequently unauthorized pumps—to locally boost water pressure. While this may improve water pressure or flow rate at the pump's location, negative consequences propagate through the water distribution system, e.g., negative pressurization in the water distribution system. The resulting negative pressurization can starve supplied water from other surrounding residences and impair water quality by drawing contaminants into the water supply. There remains a need for a water distribution system that mitigates the potentially harmful effects of unauthorized local modifications.

SUMMARY

[0004] A pressure activated self-throttling valve disposed upstream of a home can mitigate negative pressurization upstream from the valve and its resulting harmful effects on a residential water supply by tending to close when the home imposes a negative pressure on the supply. Specifically, a pinch valve or the like disposed upstream from a home can temper the home's ability to withdraw excess water from a municipality's water supply (e.g., through the use of an inline booster pump or other unauthorized components) and reduce the likelihood of contaminants being drawn into the water supply (e.g., through leaky piping). To this end, the valve may be configured to close when a pressure on the upstream side of the valve falls below a predetermined pressure. Thus, even with a pump operating at the home, when negative pressure

is imposed on the supply the valve will tend to close and prevent the home from overdrawing or potentially contaminating the water supply.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The foregoing and other objects, features, and advantages of the devices, systems, and methods described herein will be apparent from the following description of particular embodiments thereof, as illustrated in the accompanying figures. The figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the devices, systems, and methods described herein.

[0006] Fig. 1 illustrates a booster pump configuration to improve water flow from a residential water supply system at a home.

[0007] Fig. 2 illustrates an alternative booster pump configuration to improve water flow from a residential water supply system at a home.

[0008] Fig. 3 illustrates the effects of booster pumps in a water supply system.

[0009] Fig. 4 illustrates a generalized model of a pressure activated valve.

[0010] Fig. 5 illustrates a water supply system with valves disposed upstream from endpoints.

[0011] Fig. 6 is a graphical representation of water pressure in a residential water supply system using a self-throttling valve.

[0012] Fig. 7 is a side view of a self-throttling valve.

[0013] Fig. 8 is a cross-sectional view of a self-throttling valve.

[0014] Fig. 9 is an exploded view of a self-throttling valve.

[0015] Fig. 10 is a cross-sectional view of a self-throttling valve.

[0016] Fig. 11 is a cross-sectional view of a self-throttling valve.

[0017] Fig. 12 is a flow chart of a method for using a self-throttling valve.

DETAILED DESCRIPTION

[0018] The embodiments will now be described more fully hereinafter with reference to the accompanying figures, in which preferred embodiments are shown. The foregoing may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein.

[0019] All documents mentioned herein are hereby incorporated by reference in their entirety. References to items in the singular should be understood to include items in the plural, and vice versa, unless explicitly stated otherwise or clear from the text. Grammatical conjunctions are intended to express any and all disjunctive and conjunctive combinations of conjoined clauses, sentences, words, and the like, unless otherwise stated or clear from the context. Thus, the term “or” should generally be understood to mean “and/or” and so forth.

[0020] Recitation of ranges of values herein are not intended to be limiting, referring instead individually to any and all values falling within the range, unless otherwise indicated herein, and each separate value within such a range is incorporated into the specification as if it were individually recited herein. The words “about,” “approximately,” or the like, when accompanying a numerical value, are to be construed as indicating a deviation as would be appreciated by one of ordinary skill in the art to operate satisfactorily for an intended purpose. Ranges of values and/or numeric values are provided herein as examples only, and do not constitute a limitation on the scope of the described embodiments. The use of any and all examples, or exemplary language (“e.g.,” “such as,” or the like) provided herein, is intended merely to better illuminate the embodiments and does not pose a limitation on the scope of the embodiments. No language in the specification should be construed as indicating any unclaimed element as essential to the practice of the embodiments.

[0021] In the following description, it is understood that terms such as “first,” “second,” “top,” “bottom,” “up,” “down,” and the like, are words of convenience and are not to be construed as limiting terms.

[0022] Described herein are devices, systems, and methods for residential water distribution systems, and in particular residential water distribution systems using self-throttling valves to mitigate endpoint-induced negative pressurization. It will be understood that while the preferred embodiments below emphasize residential water supply systems, the principles of the embodiments discussed herein may be adapted to a wide variety of fluid distribution systems. Some examples include commercial water supply systems and other incompressible fluid supply systems. It should also be understood that while the preferred embodiments below emphasize self-throttling valves, the principles of the embodiments discussed herein may be adapted for use with other valves, e.g., any and all such valves as described herein or known in the art. Lastly, it will be understood that while the preferred embodiments below emphasize centrifugal pumps,

the principles of the embodiments discussed herein may be adapted for use with other pumps as described herein or known in the art.

[0023] It should be noted that the prior art generally teaches away from placing a throttling valve or the like upstream of a centrifugal pump that pumps an incompressible or nearly incompressible fluid such as water, blood, or hydraulic fluid, because it can lead to cavitation and pump damage. For example, cavitation in water pumping systems is known to create problems for pumps with a pressure head of more than 120m (394 feet). For this reason, design guidelines continue to teach away from the use of a self-throttling valve or the like, even in the case of smaller centrifugal pumps, i.e., with a pressure head less than 120m.

[0024] Although several existing patents are directed to the use of throttling valves disposed upstream of positive displacement pumps, or to throttling valves disposed upstream of pumps in biological systems thereby mimicking biological responses to pressure scenarios, (some examples of the foregoing include U.S. Pat. No. 8,222,276; U.S. Pat. No. 5,363,649; U.S. Pat. No. 2,433,220; U.S. Pat. No. 4,741,675; U.S. Pat. No. 5,813,842; and U.S. Pat. No. 7,435,059), the prior art does not include, and generally teaches away from the use of throttling valves disposed upstream from centrifugal pumps and the like in water supply systems. It should be noted that positive displacement pumps are generally designed to output a constant flow rate independent of the pressure output required, and therefore it may not be feasible to use a throttling valve downstream of such a pump as it would cause undesirably high pressures. Instead such systems place a throttling valve upstream of the positive displacement pump. It should also be further noted that such positive displacement pump systems are typically much less sensitive to cavitation damage than centrifugal pumping systems. Notwithstanding the landscape of the prior art recited above, the practice of water supply system design, construction, and operation continues to teach away from the use of a throttling valve or the like disposed upstream of a pump. Thus, the embodiments described herein generally include a counterintuitive application to water safety in water supply systems for preventing contaminant intrusion and over withdrawal of water from the water supply system.

[0025] As stated above, in general, self-throttling valves are not used upstream from fluid pumps because many types of fluid pumps can be physically damaged if they operate without adequate fluid flow or adequate pressurization at their inlet. This is particularly true of centrifugal pumps and the like that might be used to boost water flow at a residential endpoint.

However, where unauthorized pumps are being installed in such a way as to impose health risks and decrease performance for neighboring users, it may be appropriate for a municipality to take remedial action without regard to whether such hardware is being used within manufacturer specifications.

[0026] Figs. 1–3 provide useful context for understanding the challenges of delivering water into neighborhoods where end users do not follow regulations or other requirements.

[0027] Fig. 1 illustrates a booster pump configuration to improve water flow from a residential water supply system at a home. Specifically, Fig. 1 shows a system 100 with a water supply line 102, a pump 104, residential piping 106, and an overhead storage tank 108. The system 100 of Fig. 1 represents a common scenario in many houses worldwide, where houses actively pump water up from the ground level to overhead storage tanks 108 to compensate for low system pressures. The overhead storage tanks 108 then create pressure for household water use.

[0028] The water supply line 102 may be piping that provides water from a residential water supply system (which includes the water supply line 102). The residential water supply system may be operated by a municipality or other government agency, or any other public or private water utility company or organization. The pump 104 may be any booster pump known in the art, e.g., a centrifugal pump or the like (types of pumps are described in more detail below). The residential piping 106 may include piping within a house and privately owned by a homeowner, or piping leading to a storage tank for the house, e.g., the overhead storage tank 108.

[0029] In the system 100 of Fig. 1, in order to make use of the overhead storage tank 108, a user (e.g., a customer, a homeowner, a resident, and so forth) may connect the pump 104 directly to the supply line 102. This configuration may draw excess water from the supply line 102 causing a negative pressure to propagate back through the residential water system. As such, this configuration is typically prohibited by local law, regulation, utility rule, or the like. At the same time, a utility provider may be hesitant to disconnect such a system, even where it is known to be in violation of applicable rules, because it may deprive residents of running water, particularly residents on upper floors of a building supplied by the residential piping 106 and overhead storage tank 108. It will be understood that the pump 104 may also or instead connect

directly to an in home water distribution system, e.g., by directly supplying water to taps at, above, or below ground level.

[0030] Pumps 104 connected directly to the water supply line 102, such as in the system 100 of Fig. 1, may be problematic for several reasons. The negative pressure, which the pumps 104 can create at their inlet, can cause system contamination by drawing contaminants into the water supply from residential endpoints (e.g., the water supply pipes may be leaky, and they may run through ground contaminated by leaky sewage pipes, where contaminants may be sucked into the leaky water supply pipes by the negative pressure condition). The system 100 may also decrease the total system pressure and starve surrounding houses of water. This latter condition can lead to “pump wars” in which neighbors without booster pumps are so deprived of water that they are forced to install pumps themselves further exacerbating the problem. It will be understood that, while Fig. 1 shows a booster pump installed to supply a roof-based storage tank or the like, similar problems may be created in any home configuration where a pump is directly coupled to the residential water supply.

[0031] Fig. 2 illustrates a booster pump configuration to improve water flow from a residential water supply system at a home. Specifically, Fig. 2 shows a system 200 with a water supply line 202, a pump 204, residential piping 206, an overhead storage tank 208, and a sump 210. The sump 210 may include an underground sump or the like, where the system’s water supply line 202 ends in the sump 210. The pump 204 may then pull water 212 from the sump 210. In this system 200, the pump 204 may supplement pressure so that water 212 can be lifted up to an overhead storage tank 208 or the like, but it does not change the total amount of water 212 a household receives from the system 200 as compared to an equivalent household with only a tap at ground level.

[0032] The system 200 of Fig. 2 represents a configuration that solves some of the problems associated with the system 100 of Fig. 1 by avoiding a direct connection of a pump to the residential water supply. The system of Fig. 2 is generally permitted or encouraged by local rules because it prevents a home from imposing negative pressure on the residential water supply and it decouples supply in a manner that prevents backwards infiltration from the home into the supply. Nonetheless, the system of Fig. 2 still has major drawbacks that make it undesirable to many users in poor neighborhoods. Known disadvantages include a high installation cost, possible health risks of underground sumps, and the inability to increase water flow beyond what

is available from the residential water supply at ground level and atmospheric pressure. In other embodiments, a household may have two or more pumps, such as a first pump to feed a sump and a second pump to pump from the sump up to an above ground storage tank.

[0033] Fig. 3 illustrates the effects of booster pumps in a water supply system. In general, the flow of water from a water main to a household is proportional to the pressure drop between those two points according to the Hazen-Williams Formula:

$$[0034] \quad Q \propto (P_{city} - P_{house})^{\frac{1}{1.85}}$$

[0035] Booster pumps may have different effects on a water supply system depending on, e.g., their size, the water supply pressure, the endpoint (e.g., household) elevation, and pipe friction between the supply and the endpoint. Fig. 3 shows various representative cases of the effects and consequences of booster pumps, where the vertical axis 302 represents water pressure (hydraulic grade line) and the horizontal axis 304 represents the position along the pipe between the water supply line and the household connection. The dashed lines generally represent the flow of water, where areas below the horizontal axis 304 represent a negative pressure. Further, although the representations in Fig. 3 are general in nature, and are not intended to represent precise pressurization with great accuracy in any particular location, the slope of the dashed line in such a pressurization graph is generally proportional to the fluid flow to the 1.85 power (see Hazen-Williams Formula above).

[0036] In general, when pipe pressures become negative, the natural leaks in a pipe network may stop leaking clean water out and allow for contaminants to infiltrate, thereby contaminating a water supply. Specifically, whenever a pipe is not positively pressured, contaminants may infiltrate through holes and cracks in the pipe network and may create significant quality and contamination concerns. An endpoint in the water supply is shown as a residence 316 in the cases illustrated in Fig. 3, although the endpoint may be any residential or commercial facility ranging from a single family home to a multi-family dwelling or large residential building complex.

[0037] When the pressure of the water supply is high as represented by point 312, a residence 316 with ground floor taps or tanks as represented by point 314 may receive high flow rates without a booster pump. In other words, the steep slope of the dashed line 318 at the home indicates a high flow rate. Where the residence 316 is taller, or has a rooftop water storage tank 324, the higher points receive lower flow rates even when the pressure of the water supply is

high, as indicated by a second line 320. In other words, pressure and flow rates are lower for points higher above ground. Where a booster pump is used to lift water from a sump to the rooftop water storage tank 324, the flow shown by a third line 319 generally matches the flow shown by the dashed line 318 above, except that the available flow rate at ground level is lifted up to the rooftop water storage tank 324 by the booster pump as indicated by a fourth line 330.

[0038] Significant difficulties can arise when pumps are coupled directly to water supplies. For example, a fifth line 340 shows a configuration where a pump is coupled directly to the water supply and used to feed a rooftop water storage tank 324. While a substantial flow rate is transferred to the tank, even greater than available from a properly installed booster pump and sump, a negative pressure 342 can occur in the residential water supply leading to the house. This negative pressure 342 may result in the residence 316 receiving more water than neighbors, along with the other attendant negative consequences of reverse pressurization of the residential water supply system. Similar problems may arise where the pump is used to directly pressurize a ground level tap, sump, or otherwise coupled directly to the residential water supply system. Additionally, where depressurization causes low, zero, or negative pressure at surrounding houses, this may lead to widespread use of booster pumps, further reducing the system pressure and exacerbating the consequences of negative pressure.

[0039] The systems and methods described herein address these negative consequences by preventing individual residences from overdrawing the water supply. In general, water withdrawal is governed by the pressure differential between a water supply and a house. If a sump or the like is used, or a simple ground level tap (i.e., without a rooftop tank or other supplemental source), the pressure at the house is substantially equal to the pressure of the ambient air, e.g., atmospheric pressure ($P=0$ psig), and water will flow at an unmodified rate that depends solely on the pressure of the residential water supply system at the house. By using a self-throttling valve as contemplated herein, a substantially equivalent amount of water can be consistently delivered even in the presence of a centrifugal pump or the like. In this manner, individual residences can be prevented from overdrawing the water supply and creating negative pressure in the residential water supply system.

[0040] It should be noted that the proposed configuration deviates significantly from conventional valve and pump configurations because many types of pumps will be physically damaged when operating with a low pressure condition on the suction side, a highly likely result

of a valve upstream of the pump that tends to close when the upstream pressure falls below a predetermined pressure such as atmospheric pressure. To further appreciate this distinction and to illustrate the unique operation of the proposed system, a number of different pressure-sensitive valves are now described.

[0041] Fig. 4 illustrates a generalized model of a pressure activated valve. In general a pipe 404 may include a valve 402 separating an upstream side 406 of the pipe 404 from a downstream side 408 of the pipe 404, with fluid flowing through the valve 402 from the upstream side 406 to the downstream side 408 in the direction indicated by the arrows 410. A pressure differential between an upstream pressure, P_U , and a downstream pressure, P_D , creates flow through the valve 402 if there is an opening in the valve 402, i.e., the valve 402 is open. The valve 402 may operate as a pressure activated valve by tending to open or close in response to various pressure conditions, which may depend on either or both of the upstream pressure P_U and the downstream pressure P_D , as well as other pressure conditions such as a pressure set point, P_S , or any other generic control or environmental pressure, P_C . The pressure set point, P_S , may be created or supplemented by a mechanical means in the valve 402 as explained in more detail below.

[0042] Conceptually any combination of these pressures may control the valve position, although there are some common configurations such as a pressure reducing valve that tends to close when $P_D > P_S$. The valve may also, for example, include a valve that closes or substantially closes when $P_D < P_S$. This configuration may be used, e.g., to detect a downstream pipe burst where the valve 402 closes to prevent additional leakage, and may include a dedicated pressure sensing line, provided it is connected to P_D . The valve 402 may instead include a valve that closes or substantially closes when $P_U > P_S$. This configuration may be used, e.g., as an emergency drain valve that opens after a power failure, e.g., to drain a chemical which would degrade a system, and may include a dedicated pressure sensing line connected to P_U .

[0043] Where the valve 402, or another valve, tends to close when either $P_U > P_S$ or $P_U < P_S$, the valve may be referred to as a pressure sustaining valve, a back-pressure sustaining valve, a pressure maintaining valve, a back-pressure maintaining valve, a back-pressure regulating valve, and so forth. The term “self-throttling” valve, as used herein, is specifically intended to refer to valves that operate in this manner, with the valve tending to close when the upstream pressure, P_U , is equal to or below the set-point pressure, P_S . The various other valve

classifications are noted here in order to specifically distinguish the proposed configuration from other valve/pump combinations. While various combinations of valves and pumps have been used in various applications, including valves upstream of pumps and valves downstream of pumps, the proposed configuration uniquely positions a self-throttling valve upstream of a fluid pump (such as a centrifugal pump) in a water supply system, where the self-throttling valve tends to close when an upstream pressure for the valve falls below a predetermined pressure set point.

[0044] A variety of suitable membrane-based valves and the like are described below. It will be noted that while the preferred embodiments utilize passive valve configurations (e.g., for low-cost applications) with a passive pressure activated valve to throttle flow, similar responses may be achieved through alternate embodiments having active valve systems that measure pressure and electromechanically control a valve in response to the measured pressure. It will also be noted that valve operation is preferably continuous. That is, where a valve completely opens and closes in step-like or nearly instantaneous manner as the upstream pressure moves above or below the set point, the valve may tend to flutter or swing rapidly between open and closed positions, particularly where the closing valve causes pressure to once again rise in the upstream region. This may damage the valve or the residential water supply system, and inhibit smooth operation. Thus, the valve may be configured so that it tends to close around the set point (or above or just below the set point), and provides a varying degree of constriction and flow rate reduction as the upstream pressure transitions from above the set point to below the set point. This type of operation is often referred to as a throttling operation, and the proposed valve may usefully be a throttling valve that closes continuously over a range of pressures around the reference pressure (i.e., the set point pressure), or a throttling valve that responds to a drop in pressure on the upstream side below a reference pressure by closing at least partially to reduce a flow rate through the valve. More generally, any suitable valve that operates substantially as described herein to prevent upstream propagation of negative pressure may be usefully employed as a valve as contemplated herein.

[0045] A residential water supply system using pressure activated self-throttling valves is now described in greater detail.

[0046] Fig. 5 illustrates a water supply system with valves disposed upstream from endpoints. The system 500 may be a residential water supply system operated, for example, by a municipality or other government agency, or an agent thereof. The system 500 may be designed

to prevent negative pressure caused by directly-connected booster pumps at individual residences from propagating throughout the residential water supply system. In general, the system 500 may include a water main 502, a water supply feed 504, a valve 506 (e.g., a pressure activated valve), and an endpoint including a home 508 or the like.

[0047] The water main 502 may include a pipe or series of pipes (i.e., a piping system) and any associated valves, fittings, supplies, pumps, and so forth. The water main 502 may be provided by a municipality to supply water to a plurality of homes 508. The water main 502 may include one or more loops for supplying water, or may include a termination point. The water main 502 may include a plurality of water supply feeds 504 in a network that supplies water to endpoints such as homes 502, buildings, and so forth. The water main 502 may include or be supplied from a water source such as a reservoir, a water treatment plant, a dam, a well, a lake, a river, a stream, a water, tank, or any combination of the foregoing.

[0048] The water supply feed 504 may include a residential water supply feed between a residential water supply (e.g., the water main 502) and a home 508. The water supply feed 504 may be tapped off of the water main 502 and configured to deliver water to one or more homes 508. The water supply feed 504 may include a pipe or network of pipes (i.e., a piping system), and any associated valves, fittings, and so forth. Similar to the water main 502, the water supply feed 504 may be supplied by a municipality or the like. In one aspect, the water supply feed 504 is supplied by a municipality up until a certain location such as a property line 510 or the like at which point an owner of a property, e.g., a home 508, becomes responsible for the water supply feed 504. The property line 510 may include a line or boundary between public and private property, or some other demarcation or boundary. In another aspect, a homeowner or property owner is responsible for the entire water supply feed 504.

[0049] In order for the municipality to controllably deliver water to homes 508, the system 500 may include a separate valve 506 between the water supply feed 504 and each one of, or the majority of, the plurality of homes 508. Thus, the water main 502 may include a water supply feed 504 that couples to multiple homes as illustrated in a first subsystem 522, or the water main 502 may include a water supply feed 504 that couples to a single home 508 as illustrated in a second subsystem 524. More generally, a water supply feed 504 as contemplated herein may include any portion of a residential water supply system such as a single branch, a

network of branches, or some combination of these, or any other portion of the residential water supply system between a water supply and a home 508.

[0050] The valve 506 may be positioned in a residential water supply feed (e.g., the water supply feed 504 shown in Fig. 5) between the water supply (e.g., a water supply 501 or the water main 502) and the home 508. The valve 506 may be disposed outside of a property line 510 (e.g., a boundary between public and private property) where the valve 506 can be installed, controlled, and accessed by a municipality or the like. The valve may also or instead be installed inside of the property line 510 at or before a termination of the water supply feed 504. The valve 506 may be tamper-resistant, tamper-proof, or otherwise secured to prevent homeowners from circumventing the valve 506 or interrupting its intended function.

[0051] The valve 506 may include an upstream side 512, a downstream side 514, and a reference pressure port 516. The upstream side 512 may generally include any portion of the water supply feed 504 that is disposed between the water main 502 and the valve 506. The downstream side 514 may generally include any portion of a piping system that is disposed between the valve 506 and an endpoint, e.g., the residential piping 518 that feeds a home 508. The residential piping 518 may generally refer to piping after the valve 506, i.e., the downstream side 514 piping, including both piping internal to the home 508 and external to the home 508.

[0052] The reference pressure port 516 may include a location or region where the reference pressure is obtained or a location where an equivalent mechanical force is provided. This location or region may be different from the input and output of the valve 506. In another aspect, the reference pressure port 516 may include the input or output of the valve 506. The reference pressure port 516 may include a designated location or region that is specifically designed for obtaining the reference pressure, e.g., a pressure chamber or the like that provides a fixed set point for operation of the valve 506. The reference pressure port 516 may also or instead include another location, e.g., a generic location pneumatically coupled to the valve to facilitate external control of the fixed set point. The reference pressure port 516 may thus include any location that provides a reference pressure, a predetermined pressure, or any other fixed or variable/controllable pressure. The reference pressure port 516 may also or instead include a spring-activated control or other mechanical proxy for pressure to effectively provide a reference point for pressure-activated operation.

[0053] The valve 506 may be configured such that the valve 506 closes at least partially when a pressure on the upstream side 512 of the valve 506 is below a reference pressure on the reference pressure port 516. The reference pressure may be selected to prevent a pump 520 (e.g., a centrifugal pump) at the home 508 from increasing a flow rate from the residential water supply feed (e.g., either or both of the water supply feed 504 or the water main 502) at the home 508. The reference pressure may also or instead include an ambient atmospheric pressure, which suitably prevents flow through the valve from dropping a pressure on the upstream side of the valve 506 below atmospheric pressure. In one aspect, the reference pressure is selected to prevent propagation of a negative pressure beyond a predetermined threshold from the home 508 to the residential water supply (e.g., the water supply feed 504 or the water main 502). The reference pressure may include a single value, a range of values, an average value, and so on. The valve 506 may in general be any valve that is capable of sealing or partially sealing when pressure drops below some predetermined threshold. The valve 506 may also or instead restrict flow through the valve 506 to the home 508 by another means. The valve 506 may be configured to continuously self-regulate, self-seal, self-throttle, etc., by automatically opening and closing to maintain an upstream pressure at or above a predetermined set point. As described herein, a preferred embodiment includes a self-throttling valve that mitigates fluttering and related valve behaviors that might damage other system components in the adjacent fluid distribution network.

[0054] The reference pressure may include a pressure set point that is created by a mechanical component of the valve 506. For example, the valve 506 may include an adjustable spring or other mechanical means for creating a set point which may be represented by a pressure set point, i.e., the reference pressure. The mechanical means may be constructed to vary their equivalent set point as a function of valve closure. Thus, in an embodiment the set-point pressure can include mechanical means of mimicking such a pressure, which may be located at the reference pressure port 516.

[0055] The valve 506 may be integrated into an auxiliary component 534, such as a water meter (e.g., where the valve 506 is integrated into the water meter—the valve's body may be embedded within a water meter), another valve (e.g., an air release valve or the like, where the valve 506 is integrated into the air release valve—the valve's body may be embedded within an air release valve), or any combination thereof. The auxiliary component 534 may also or instead include a pressure gauge or pressure sensor, or another type of sensor or piece of equipment. The

auxiliary component 534 may also or instead be part of the valve 506 (e.g., integrated into the valve 506), may include the valve 506 (e.g., where the valve 506 is integrated into the auxiliary component 534), may be connected to, engaged with, or in communication with the valve 506, and so forth. An auxiliary component 534 may also or instead be separate from the valve 506 but nevertheless part of the system 500.

[0056] The valve 506 may also or instead be integrated into a fluid pump installed at the home 508, e.g., the pumps 520 shown in Fig. 5. In one aspect, when the valve 506 is integrated into a fluid pump, it is located on the suction side of the pump. The valve 506 may include a throttling valve. The throttling valve may close continuously over a range of pressures around the reference pressure. The throttling valve may also or instead respond to a drop in the pressure on the upstream side 512 below the reference pressure by closing at least partially to reduce a flow rate through the valve 506. The valve 506 may also or instead include a pinch valve, for example, a pinch valve as explained in more detail below with reference to Figs. 7–9. The valve 506 may also or instead include a self-actuating valve.

[0057] In a preferred embodiment, the valve 506 is a self-throttling valve as described herein. The valve 506 may also or instead include without limitation a ball valve, a butterfly valve, a disc valve, a check valve, a choke valve, a diaphragm valve, a gate valve, a globe valve, a needle valve, a piston valve, a plug valve, a solenoid valve, a pressure reducing valve, a safety or relief valve, a pressure sustaining valve, a back-pressure regulator, and so forth. The valve 506 may also or instead include a vacuum breaker, a backflow preventer, and so forth. In one aspect, the valve 506 includes a Starling resistor. One suitable valve 506 is described by way of example in U.S. Pat. No. 3,039,733, which is hereby incorporated by reference in its entirety. The valve 506 may in general be configured to regulate the flow or pressure of a fluid as described herein, and may include any mechanical, electrical, or electromechanical elements to support this function.

[0058] In one aspect the valve 506 may include an actively controlled valve. The valve 506 may thus include a control valve that responds to signals generated by an independent device such as a flow meter, a pressure meter, and so forth. The valve 506 may be fitted with actuators, positioners, and the like, e.g., used for control purposes. The actuators may be hydraulic or pneumatic actuators that provide automatic control where the actuators respond to changes of pressure or flow and will open/close the valve 506. The actuators may include plunger-type

actuators, electromagnetic actuators, and so forth. The valve 506 may not require an external power source, e.g., if the valve 506 utilizes hydraulic actuators where the fluid pressure is enough to open and close the valve 506. The valve 506 may instead include an external power source, e.g., electric, pneumatic, or man power. The valve 506 may also or instead be manually controlled. The valve 506 may also or instead include a passively operated or controlled valve (i.e., a self-operating valve) that requires no such power or controls.

[0059] The valve 506 may include, or work in conjunction with, sensors and transmitters that collect information about a system variable (e.g., flow, pressure, or the like) and its relationship to a desired set point. A controller may then process this information and determine a course of action (e.g., closing the valve) that can get the process variable back to the desired set point or desired range.

[0060] In one aspect, the valve 506 may include or be replaced by an orifice in a pipe, tube, opening, or the like, where the orifice is sized and calibrated such that it only allows a certain flow rate through the pipe. The orifice may include a static size and shape (e.g., the size and shape of the orifice may be permanent) with other hardware that adapts flow rate according to pressure, or the orifice may change its size and shape depending on certain conditions, e.g., pressure or flow conditions.

[0061] In a preferred embodiment, the devices, systems, and methods described herein include a self-throttling valve disposed upstream from a centrifugal pump. However, the pump 520 may in general include any device that moves fluids such as water by mechanical action. The pump 520 may be any pump or similar device suitable for increasing pressure or flow rate in a residential water supply. The pump 520 may include a reciprocating or rotary mechanism to move the fluid. The pump 520 may operate via an energy source including without limitation manual operation, electricity, internal combustion engines (e.g., gas, diesel, and so forth), wind power, solar power, and so forth. The pump 520 may include a velocity pump (e.g., centrifugal or radial-flow pump, axial-flow pump, mixed flow pump, eductor-jet pump, and so forth), a positive displacement pump (e.g., gear pump, screw pump, plunger pump, impeller pump, and so forth), an impulse pump (e.g., hydraulic ram pump), and so forth.

[0062] The endpoint may include a home 508 (e.g., apartment complex, building, house, dwelling area, and so forth) as shown in Fig. 5. It shall be understood that any reference herein to a home 508 shall include other endpoints unless explicitly stated otherwise or clear from the

context. The endpoint may also or instead include a commercial, industrial, or government building, a park, a school, a hospital, or the like. In general, the endpoint may include any building, structure, area, and so forth that is supplied (or is configured to be supplied) by the water main 502 and water supply feed 504. The endpoint may be a portion of the system 500 where piping or the like terminates, or it may be included as part of a loop.

[0063] The home 508 may include fixtures or items that use water or the like supplied by the system 500. Such fixtures may include without limitation faucets, showers, tubs, spouts, wells, dishwashers, washing machines, air conditioners, humidifiers, pools, tanks, tubs, sprinklers, fountains, and so forth. The system 500 may supply water, e.g., potable or non-potable water. The system 500 may also or instead supply another fluid, e.g., gas, steam, and so forth.

[0064] As explained above, the system 500 of Fig. 5 may include numerous subsystems, including a first subsystem 522 and a second subsystem 524. The first subsystem 522 may include a plurality of homes 508 connected to the water main 502 through one water supply feed 504, e.g., a first home 526 and a second home 528. In contrast, the second subsystem 524 may include only one home 508 connected to the water main 502 through one water supply feed 504.

[0065] The first home 526 of the first subsystem 522 includes a pump 520 that feeds a water tank 530. The first home 526 may thus include a relatively large home 526 such as an apartment complex or the like. The water tank 530 may be disposed at an elevated location such that it can use gravity to feed the first home 526 with water that is stored in the water tank 530. The water tank 530 may include any means for storing water or the like. The water tank 530 may include its own separate water tank pump or the like, e.g., for filling the water tank 530 or distributing water from the water tank 530.

[0066] The second home 528, in contrast to the first home 526, may not include a pump, tank, or the like, but instead includes residential piping 518 on the downstream side 514 of the valve 506 that directly feeds the second home 528, e.g., directly supplies water to fixtures in the second home 528.

[0067] The first subsystem 522 represents a preferred embodiment that includes a valve 506 for each home 508 as shown. Alternatively, homes 508 may also or instead share a single valve 506. For example, a valve 506 may be disposed upstream from the valves 506 shown in Fig. 5, i.e., before the water supply feed 504 splits into two separate branches that feed the first

home 526 and the second home 528. This shared valve may replace or supplement the valves 506 shown for the first subsystem 522.

[0068] The second subsystem 524 may include only one home 508 connected to the water main 502 through one water supply feed 504, and may further include a sump 532 or the like. Thus, the devices, systems, and methods described herein may work in conjunction with or without a sump 532 as demonstrated by the second subsystem 524, or more generally with any combination, number, and configuration of homes 508 that might be found in a residential water supply system. The use of valves 506 such as the valves described herein at each home 508 generally prevents negative pressure from any or all of the homes 508 from affecting the water main 502 and water supply feeds 504.

[0069] Fig. 6 is a graphical representation of water pressure in a residential water supply system using a self-throttling valve. In general, the graph 600 of Fig. 6 may represent the hydraulic grade line at a typical residential connection both with and without a valve installed upstream of a home. In the graph 600, the vertical axis 602 represents pressure, where the supply pressure 604 is represented by a horizontal line along the vertical axis 602. The horizontal axis 606 may represent the distance from a water main 608 to a building 610 such as a multiple story home. The horizontal axis 606 may also or instead represent the ground level 612. The graph 600 further includes illustrative examples of a water supply line 614, a water meter 616, a pressure logger 618, a valve 620, a booster pump 622, and a water tank 624. The graph 600 illustrates a first pressure profile 626 representing a scenario without a valve 620 installed upstream of the building 610 and its pump 622 (the first pressure profile 626 is shown as a dotted line), and a second pressure profile 628 representing a scenario with a valve 620 installed upstream of the building 610 and its pump 622 (the second pressure profile 628 is shown as a dashed-dotted line). It should be noted that the pressure logger 618 may only be present for verification of the performance of the valve 620.

[0070] The first pressure profile 626 shows a first negative pressure area 630 representing a negative pressure (pressure less than 0 psi) that may be induced in the water supply line 614 leading to the building 610, e.g., when the supply pressure 604 of the water main 608 is low (e.g., less than 8 psi). As explained herein, negative pressure scenarios may be exacerbated by the inclusion of a booster pump 622 in a water supply system.

[0071] The second pressure profile 628 shows how negative pressure scenarios may be mitigated with the unconventional use of a valve 620 installed upstream of the building 610 and booster pump 622, e.g., a self-throttling back-pressure regulating valve or the like. In one aspect, the valve 620 is configured to throttle the flow of water through the valve 620, which can limit the existence of negative pressure to downstream of the valve. In another aspect, the smaller second negative pressure area 632 between the valve 620 and the booster pump 622 may lead to increased cavitation in the booster pump 622. As discussed above, the prior art suggests that self-throttling valves should never be placed upstream of rotary pumps for fear of this cavitation. Contrary to this, the devices, systems, and methods described herein may include a valve 620 that is designed specifically to cause this ‘undesirable’ cavitation as it in turn may force the booster pump 622 to operate on a modified pump curve, enforcing a slower flow rate, reducing upstream frictional losses, and therefore maintaining positive upstream pressure. It should be noted that, although shown as the same, the first pressure profile 626 and the second pressure profile 628 may have slightly different flow rates after the pump 622.

[0072] In this context, there are a number of desirable properties for the valve 620, many of which are satisfied by the valves described below with reference to Figs. 7–9. The valve described below, for example, can usefully sustain positive back-pressure (e.g., a regulating valve that opens when the upstream pressure is greater than 0 psi and closes when the upstream pressure is less than 0 psi). The valve below may present low frictional losses when open. The valve may have a low part count with few or no active components to improve reliability and reduce cost. The valve is preferably stable in throttling (e.g., intermediate) positions. The valve may withstand cyclical loading at, e.g., –10 psi and +100 psi. The valve may usefully provide a relatively high burst pressure (e.g., >140 psi) to reduce possible malfunctions, and the valve should be safe for continuous potable water contact (e.g., include NSF 61 materials). The valves may also usefully have a strength higher than standard piping. The valves described herein, and in particular with reference to Figs. 7–9, may satisfy any or all such functional aspects.

[0073] Fig. 7 is a side view of a self-throttling valve. The valve 700 may include a self-throttling valve as described in the systems and methods discussed above, e.g., a self-actuating, full-bore, back-pressure regulating valve suitable for placement upstream from an endpoint in a water supply system. In one aspect, the valve 700 may include a pinch valve. In one aspect, the

valve 700 may be a sealed vacuum prevention valve that limits negative pressures by closing instead of venting to the atmosphere, thereby limiting instances of contamination.

[0074] The valve 700 may include a housing 702 that holds an outer shell 704 that houses internal components of the valve 700. The valve 700 may also include engagement ends 705 which may be threaded or otherwise formed for coupling to pipes or other fluid conduits.

[0075] The housing 702 may include any suitable material to house the components of the valve 700 including without limitation metal, plastic, ceramic, and so forth. In one aspect, the housing 702 is made from a synthetic plastic polymer such as polyvinyl chloride (PVC) or the like. The housing 702 may include a PVC reducer or the like. For example, the housing 702 may include an unthreaded pipe reducer from 2 inch to 1/2 inch such as McMaster-Carr® Model No. 6826K192 or similar.

[0076] The outer shell 704 may hold, protect, stabilize, or generally house the internal components of the valve 700. The outer shell 704 may be economically made from a plastic such as PVC or the like. In one aspect, the outer shell 704 is made from a 2 inch PVC pipe, e.g., a schedule 40 PVC pipe. The outer shell 704 may also or instead be made from another material such as a metal, fiberglass, and so forth, e.g., in order to provide a greater degree of strength and robustness. In general, the outer shell 704 may discourage or prevent tampering. The outer shell 704 may also or instead provide room for expansion, a pressure chamber, and so on. The outer shell 704 may thus act as a plenum with a nominal reference pressure equal to the highest expected atmospheric pressure that the valve 700 would normally encounter, such that the valve 700 need not be referenced to the external atmosphere (this configuration could virtually eliminate the potential for tampering).

[0077] The engagement ends 705 may be configured for engagement with a pipe, ferrule, or the like in a water supply system. The engagement ends 705 may include a threading (e.g., a NPT threading) or the like. The engagement ends 705 may be made from a material that is stronger than standard piping.

[0078] Fig. 8 is a cross-sectional view of a self-throttling valve. Specifically, Fig. 8 may be a cross-sectional view of the valve shown in Fig. 7. The valve 800 may include a housing 802 that holds an outer shell 804, and may also include internal components such as a reinforcing shell 806, a tube 808, and an insert 810. In general, the valve 800 may be actuated by a flexible membrane (e.g., the tube 808) that collapses when the pressure inside of the membrane is less

than the pressure outside of the membrane. The valve 800 may be configured to be fully open when the pressure of the water supply at the valve 800 relative to the reference pressure outside the membrane is greater than or equal to zero psi and about 95% closed when a difference between the pressure of the water supply at the valve and the pressure outside the membrane is less than zero psi. The valve 800 may also be designed such that it is tamper proof, safe for contact with potable water, it defaults to an open position if any failure occurs, is easily mass produced, is inexpensive (e.g., about \$15 each), and durable (e.g., will last for 5–10 years or more). While the reference pressure outside the membrane may be obtained from a sealed chamber or other reference source, it will be appreciated that the reference pressure may usefully be about one atmosphere, which can be readily obtained by venting or otherwise coupling the area outside the membrane to the atmosphere.

[0079] The reinforcing shell 806 may include material to strengthen, support, protect, and generally hold the tube 808 and insert 810. The reinforcing shell 806 may be made from a wire mesh or the like. In one aspect, the reinforcing shell 806 may be a mesh tube constructed of a rolled mesh material (e.g., a thin wire mesh rolled around an outer layer of A-50 silicon rubber material). The reinforcing shell 806 may act as a positive pressure stress relief for the tube 808, which may be made of a softer material. The reinforcing shell 806 may be present in one aspect because the tube 808 is substantially flexible such that under a positive pressure condition (which is the normal operating condition) it balloons significantly. The reinforcing shell 806 may thus be configured to prevent ballooning of the tube 808 at a high pressure and to carry a substantial portion of the positive pressure load. In one aspect, the reinforcing shell 806 may be replaced or supplemented by an embedded rope mesh within the tube 808, or the reinforcing shell 806 or a reinforcing means may be otherwise integrated into the tube 808.

[0080] The tube 808 may be disposed inside of the reinforcing shell 806. The tube 808 may be made from a flexible material, and may thus include an elastomeric material such as rubber, e.g., A-35 silicone rubber, a latex rubber, or the like. The tube 808 may include a hose or hose-like structure or material. The tube 808 may be used as the actuator in the valve 800. To this end, the tube 808 may collapse into the insert 810 (e.g., a cutout 812 in the insert 810) under negative pressures. When the tube 808 collapses, it may adopt the profile of the insert 810, e.g., the profile of the cutout 812. The tube 808 may include a thickness of about 1/16 inches and have an inner diameter of about 3/4 inches. The tube 808 may generally be a soft tube that allows

for itself to collapse when the pressure inside of the tube 808 is less than the pressure outside of the tube 808. For example, the tube 808 may be fully open when the pressure inside of the tube 808 is greater than or equal to zero psi (relative to the pressure outside the tube) and about 95% closed when the pressure inside of the tube 808 is less than zero psi. The tube 808 may also or instead be less than fully open, or more closed (e.g., fully closed), under certain pressure conditions. In one aspect, the tube 808 is configured to prevent instability or fluttering between its open and collapsed positions when installed upstream of a booster pump. To this end, the tube 808 may be fitted with the insert 810. Alternatively, the tube 808 may be pre-buckled with a twist or the like, fixed with a gradual transition section, or otherwise physically pre-loaded for more stable operation. Thus, in one aspect, the tube 808 does not include an insert 810. In general, the tube 808 may act as a stabilized collapsing membrane or tube-like structure. The tube 808 may instead include alternate shapes, e.g., non-rounded shapes. For example, the tube 808 may include a membrane that isn't tube-shaped.

[0081] The insert 810 may be disposed inside of the tube 808, and may be sized, shaped, and generally configured to stabilize the tube 808. The insert 810 may be made from a flexible material or from a rigid material. The insert 810 may for example be made from a cast urethane or the like. The insert 810 may have a higher stiffness than the tube 808, and thus may be less flexible than the tube 808, in order to reinforce the shape of the tube 808. The insert 810 may include a cutout 812 along a portion thereof, e.g., a top portion as shown in Fig. 8. The tube 808 may surround the insert 810 such that it completely encloses the cutout 812. The insert 810 may include engagement ends 814 configured for engagement with a pipe, ferrule, or the like in a water supply system. The engagement ends 814 may include a threading (e.g., a NPT threading) or the like.

[0082] In general, the insert 810 may include a rigid tube with a cutout 812. The cutout 812 may be sized and shaped for optimum performance based on the design and use of the valve 800. The cutout 812 may include a linearly sloped shape where the length of the cutout 812 at its longest is five times the inner diameter of the insert 810 and where the smallest cross-sectional size is consistent for at least three times the inner diameter of the insert 810. In one embodiment, the cutout is rounded. The cutout 812 may include straight edges, curved edges, or any combination thereof.

[0083] In one aspect, the insert 810 is scaled such that its cross-sectional perimeter substantially matches the inner circumference of the tube 808. However, another ratio of cross-sectional perimeter of the insert 810 to inner circumference of the tube 808 may be used, which may be measured in a percentage that the tube 808 would have to stretch radially to occlude the pipe at the cross-sectional perimeter at the center of the cutout 812 (this can be calculated using different values for slip between the insert 810 and the tube 808). In one aspect, this ratio is 0% (i.e., along a neutral axis of the tube 808, no radial elongation is required to seal off the tube 808); in another aspect, this ratio is +20%. Other ratios are possible and other cutout 812 shapes are possible. Axial stretching along the length of the tube 808 and bending may be present. The insert 810 may be sized and shaped to prevent fluttering or instability of the tube 808.

[0084] Fig. 9 is an exploded view of a self-throttling valve such as the valve shown in Fig. 8. The valve 900 may include a housing 902 such as a PVC reducer, an outer shell 904 such as a PVC pipe, a reinforcing shell 906 such as a mesh tube, a tube 908 such as a silicon rubber hose, and an insert 910 with a cutout 912 and engagement ends 914.

[0085] The valve 900 may also include inner rings 916. The inner rings 916 may be disposed around ends of the insert 910, i.e., between ends of the insert 910 and ends of the tube 908. The inner rings 916 may be used as a strain transitioning material, and may thus be made from any suitable material to perform accordingly. The inner rings 916 may be made from a flexible material, and may thus include an elastomeric material such as rubber, e.g., A-50 silicone rubber or the like. The inner rings 916 may include a thickness of about 1/16 inches and have an outer diameter of about 3/4 inches. The inner rings 916 may also or instead stabilize, engage, or support the insert 910 with the tube 908.

[0086] The inner rings 916 may be present in one aspect because the insert 910 is substantially stiffer than the tube 908 such that a wear point occurs at the interface between the insert 910 and the tube 908. To minimize wear, short sections of a strain transition material may be used, i.e., the inner rings 916.

[0087] The valve 900 may include outer rings 918. The outer rings 918 may be disposed around ends of the tube 908, i.e., between ends of the tube 908 and ends of the reinforcing shell 906. The outer rings 918 may be made from a flexible material, and may thus include an elastomeric material such as rubber, e.g., A-50 silicone rubber or the like. The outer rings 918 may include a thickness of about 1/16 inches and have an inner diameter of about 3/4 inches. The

outer rings 918 may also or instead stabilize, engage, or support the tube 908 with the reinforcing shell 906.

[0088] In one aspect, one or more of the inner rings 916 and the outer rings 918 is replaced or supplemented by a strain matched adhesive.

[0089] The valve 900 may also include ferrules 920 or the like that crimp the internal components of the valve 900 together. The ferrules may be made from a metal, e.g., brass or the like. To prevent creeping of the materials, ribs may be used in the crimping die and barbs may be used on the insert 910. The ferrules 920 (i.e., the crimping elements) may be replaced or supplemented with an adhesive.

[0090] In assembling the valve 900, the insert 910 may first be designed and formed. The inner rings 916 may then be attached to the insert 910. The tube 908 may then be stretched over the insert 910 and inner rings 916. The outer rings 918 may then be attached to the tube 908. The entire assembly may then be rolled in the reinforcing shell 906 (e.g., a wire mesh) and crimped with brass ferrules 920.

[0091] The valve described above with reference to Figs 7–9 may prevent air from entering the tube or pipe, while adjusting in response to a difference between the pressure inside the tube or insert and the pressure on the outside of the reinforcing shell. If the reinforcing shell were sealed, the initial pressure inside the tube may still be atmospheric pressure. However, when the flexible tube collapses into the insert, it may force sealed air to expand, decreasing its pressure and creating a vacuum on the outside of the flexible tube. Since the flexible tube may control the internal pressure based on the external pressure, a negative external pressure may allow the valve to have negative pressures inside the pipe.

[0092] To increase the difficulty of tampering, the valve may be sealed inside a larger pipe which serves as a pressure chamber (e.g., the outer shell or housing). Under steady state operating conditions the closed valve may have a displaced volume of about 3 mL. If the valve were sealed in a pressure container 100 times larger than the displacement volume, it may create an error of about 1% in the pressure reading (0.15 psi). Therefore, the valve may be sealed within an outer pipe with a two inch inner diameter. In an implementation, the valve has a pressure reference volume of 218 mL and therefore a pressure error of $1.3\% = 0.2$ psi. An added benefit of the pressure chamber may be that if the flexible tube breaks, it will not leak outside of the sealed outer structure.

[0093] Fig. 10 is a cross-sectional view of a self-throttling valve. The valve 1000 in Fig. 10 may be an alternate embodiment of the valve described above with reference to Figs. 7–9. The valve 1000 may include an additional plenum or armor casing as compared to the valves discussed above. Specifically, the valve 1000 may include a housing 1002 that holds an outer shell 1004, a reinforcing layer 1006, a tube 1008, and an insert 1010. The insert 1010 of the valve 1000 may be held in place through friction. The outer shell 1004 may be made from iron pipe or the like, e.g., 1.25 inches reamed iron piping. The outer shell 1004 may include one or more outer breathing holes 1022. The reinforcing layer 1006 may serve to seal the outer shell 1004 with at least two O-ring seals 1024, prevent the collapsed tube 1008 from ballooning, and seal the collapsed tube 1008 through the use of one or more glued joints 1026 located on the outside of the reinforcing layer 1006 to reduce loading on the joints. The reinforcing layer 1006 may include one or more inner breathing holes 1023. The valve 1000 may also include a set screw 1028 or the like, which secures the reinforcing layer 1006 to the outer shell 1004.

[0094] Fig. 11 is a cross-sectional view of a self-throttling valve. The valve 1100 in Fig. 11 may be an alternate embodiment of the valves described above with reference to Figs. 7–10. The valve 1100 may include a housing 1102 that holds an outer shell 1104, a tube 1108, and an insert 1110. The housing 1102 may be made from a reducing coupling, e.g., a 1 inch to 0.5 inches NPT reducing coupling. The outer shell 1104 may be made from metal pipe or the like, e.g., a CNC turned A1 1 inch pipe with 1 inch to 0.5 inches NPT couplings. The outer shell 1104 may include one or more outer breathing holes 1122. The valve 1100 may further include plugs (e.g., threaded plugs 1128) or the like. The threaded plugs 1128 may screw axially into the valve 1100 to compress the O-rings 1124, which forms a seal between the collapsible tube 1108 and the outer shell 1104. These seals may also act to axially anchor the collapsible tube 1108 to the insert 1110, eliminating a need for any glued joints. The valves described herein may be configured for use with water supply connection pressures between about three and eight psi, where the membrane-based valves described above can usefully mitigate booster-pump-induced negative pressure and the attendant health risks and inconvenience.

[0095] Fig. 12 is a flow chart of a method for using a self-throttling valve. In general the method 1200 may be performed when a new residential water supply system is installed, or as a retrofit to an existing residential water supply system. The steps described below may generally

mitigate or prevent negative pressures in a residential water supply system, such as those caused by booster pumps.

[0096] As shown in step 1202, the method 1200 may include providing a valve, e.g., a pressure activated valve. The valve may be any of the valves described above, and may generally include an upstream side, a downstream side, and a reference pressure port. The valve may be configured to at least partially close when a pressure on the upstream side of the valve is below a reference pressure on the reference pressure port. As noted above, the valve may be integrated into another device used in the residential water supply system such as a water meter, an air release valve, or a fluid pump installed at or near the home. The valve may include a pinch valve as described above, or any other self-actuating valve that adjusts to pressure changes without active components.

[0097] As shown in step 1204, the method 1200 may include inserting the valve between a residential water supply and a home supplied by the residential water supply. The home may include a centrifugal pump or the like downstream of the valve installed by a homeowner for increasing a flow rate from the residential water supply at the home. In order to prevent the pump from creating negative pressure in the residential water supply, a reference pressure for the valve may be selected to prevent the centrifugal pump at the home from increasing the flow rate from the residential water supply feed at the home beyond some predetermined amount such as an amount that would be supplied in the absence of a pump or other active component.

[0098] As shown in step 1206, the method 1200 may include closing the valve when a pressure on the upstream side of the valve is below the reference pressure on the reference pressure port. Closing the valve may include partially closing the valve, fully closing the valve, or otherwise retarding fluid flow through the valve or in the home. The valve may be closed automatically or manually. The reference pressure may be equal to (or substantially equal to) an ambient atmospheric pressure. The reference pressure may also or instead be selected at any suitable level to prevent a propagation of a negative pressure beyond a predetermined threshold from the home to the residential water supply. The reference pressure may also or instead be selected at any suitable level to maintain a minimum level of positive pressure within the residential water supply

[0099] As stated above, closing the valve may include substantially closing the valve (e.g., 95% closed) but not fully closing the valve. While the valve's logic is generally to close if

the pressure drops below a certain point, if the valve were to seal completely, the pressure may immediately increase above that set-point pressure and reopen, and then the pressure would drop again causing it to close. Thus a valve with binary operation may flutter about a set point resulting in physical vibrations and possible damage to the valve or surrounding components of the water distribution system. The valve may thus be designed with a stabilizing component or the like, e.g., a stabilizing insert that avoids fluttering and instead includes a membrane that closes to a predetermined amount such that the pressure upstream is at or above the set point of the valve. Additionally, when the valve is installed upstream of a pump, and the valve does not completely seal, the pump may still function, albeit at a limited capacity. In this manner, a pump may still be able to add pressure to the water supply at a residence, provided the pump does not increase flow rate in a manner that causes undesirable negative pressure upstream in the system. Despite the prior art generally teaching away from placing a self-throttling valve or the like upstream of a pump as it causes cavitation and forces the pump to operate at a limited capacity, a preferred embodiment described herein includes this unconventional configuration and causes such cavitation. In this manner, a pump may still operate, albeit on a modified pump curve, thereby enforcing a slower flow rate, reducing upstream frictional losses, and therefore maintaining positive upstream pressure.

[00100] In another aspect, the method may include preventing a pump from inducing contaminant intrusion into a water supply. This may be accomplished through the installation of a throttling valve between the water supply and the pump as described above.

[00101] The method steps of the implementations described herein are intended to include any suitable method of causing such method steps to be performed, consistent with the patentability of the following claims, unless a different meaning is expressly provided or otherwise clear from the context. So for example performing the step of X includes any suitable method for causing another party such as a remote user, a remote processing resource (e.g., a server or cloud computer) or a machine to perform the step of X. Similarly, performing steps X, Y and Z may include any method of directing or controlling any combination of such other individuals or resources to perform steps X, Y and Z to obtain the benefit of such steps. Thus method steps of the implementations described herein are intended to include any suitable method of causing one or more other parties or entities to perform the steps, consistent with the patentability of the following claims, unless a different meaning is expressly provided or

otherwise clear from the context. Such parties or entities need not be under the direction or control of any other party or entity, and need not be located within a particular jurisdiction.

[00102] It will be appreciated that the methods and systems described above are set forth by way of example and not of limitation. Numerous variations, additions, omissions, and other modifications will be apparent to one of ordinary skill in the art. In addition, the order or presentation of method steps in the description and drawings above is not intended to require this order of performing the recited steps unless a particular order is expressly required or otherwise clear from the context. Rather, the method steps may be modified, reordered, supplemented, or removed without departing from the scope of this disclosure.

[00103] Thus, while particular embodiments have been shown and described, it will be apparent to those skilled in the art that various changes and modifications in form and details may be made therein without departing from the spirit and scope of this disclosure and are intended to form a part of the invention as defined by the following claims, which are to be interpreted in the broadest sense allowable by law.

CLAIMS

What is claimed is:

1. A system comprising:
a residential water supply feed between a residential water supply and a home; and
a valve positioned in the residential water supply feed between the water supply and the home, the valve including an upstream side, a downstream side, and a reference pressure port, the valve closing at least partially when a pressure on the upstream side of the valve is below a reference pressure on the reference pressure port.
2. The system of claim 1 wherein the reference pressure is selected to prevent a centrifugal pump at the home from increasing a flow rate from the residential water supply feed at the home.
3. The system of claim 1 wherein the residential water supply feed couples the water supply to a plurality of homes, the system further comprising a separate valve between the water supply and each one of the plurality of homes.
4. The system of claim 1 further comprising a water meter, wherein the valve is integrated into the water meter.
5. The system of claim 1 further comprising an air release valve, wherein the valve is integrated into the air release valve.
6. The system of claim 1 wherein the valve is integrated into a fluid pump installed at the home.
7. The system of claim 1 wherein the valve includes a throttling valve that closes continuously over a range of pressures around the reference pressure.

8. The system of claim 1 wherein the valve includes a throttling valve that responds to a drop in the pressure on the upstream side below the reference pressure by closing at least partially to reduce a flow rate through the valve.
9. The system of claim 1 wherein the valve includes a pinch valve.
10. The system of claim 1 where the valve includes a self-actuating valve.
11. The system of claim 1 wherein the reference pressure is an ambient atmospheric pressure.
12. The system of claim 1 wherein the reference pressure is selected to prevent propagation of a negative pressure beyond a predetermined threshold from the home to the residential water supply.
13. A method comprising:
 - providing a valve including an upstream side, a downstream side, and a reference pressure port, the valve closing at least partially when a pressure on the upstream side of the valve is below a reference pressure on the reference pressure port; and
 - inserting the valve between a residential water supply and a home supplied by the residential water supply.
14. The method of claim 13 wherein the home includes a centrifugal pump downstream of the valve for increasing a flow rate from the residential water supply at the home.
15. The method of claim 14 wherein the reference pressure is selected to prevent the centrifugal pump at the home from increasing the flow rate from the residential water supply at the home.
16. The method of claim 13 wherein the valve is integrated into a water meter.

17. The method of claim 13 wherein the valve is integrated into at least one of an air release valve and a fluid pump installed at the home.
18. The method of claim 13 wherein the valve includes at least one of a pinch valve and a self-actuating valve.
19. The method of claim 13 wherein the reference pressure is an ambient atmospheric pressure.
20. The method of claim 13 wherein the reference pressure is selected to prevent a propagation of a negative pressure beyond a predetermined threshold from the home to the residential water supply.

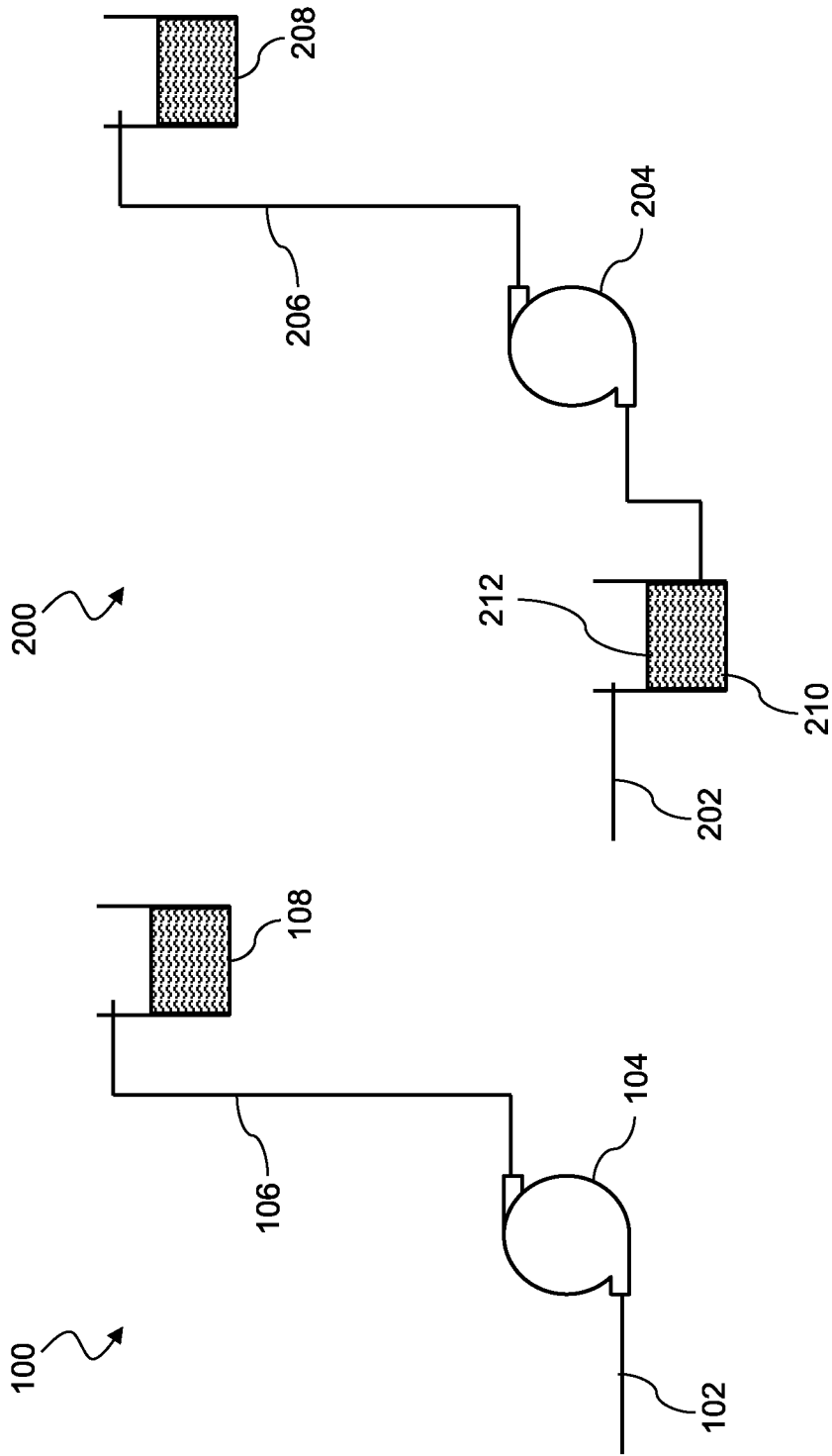


FIG. 2

FIG. 1

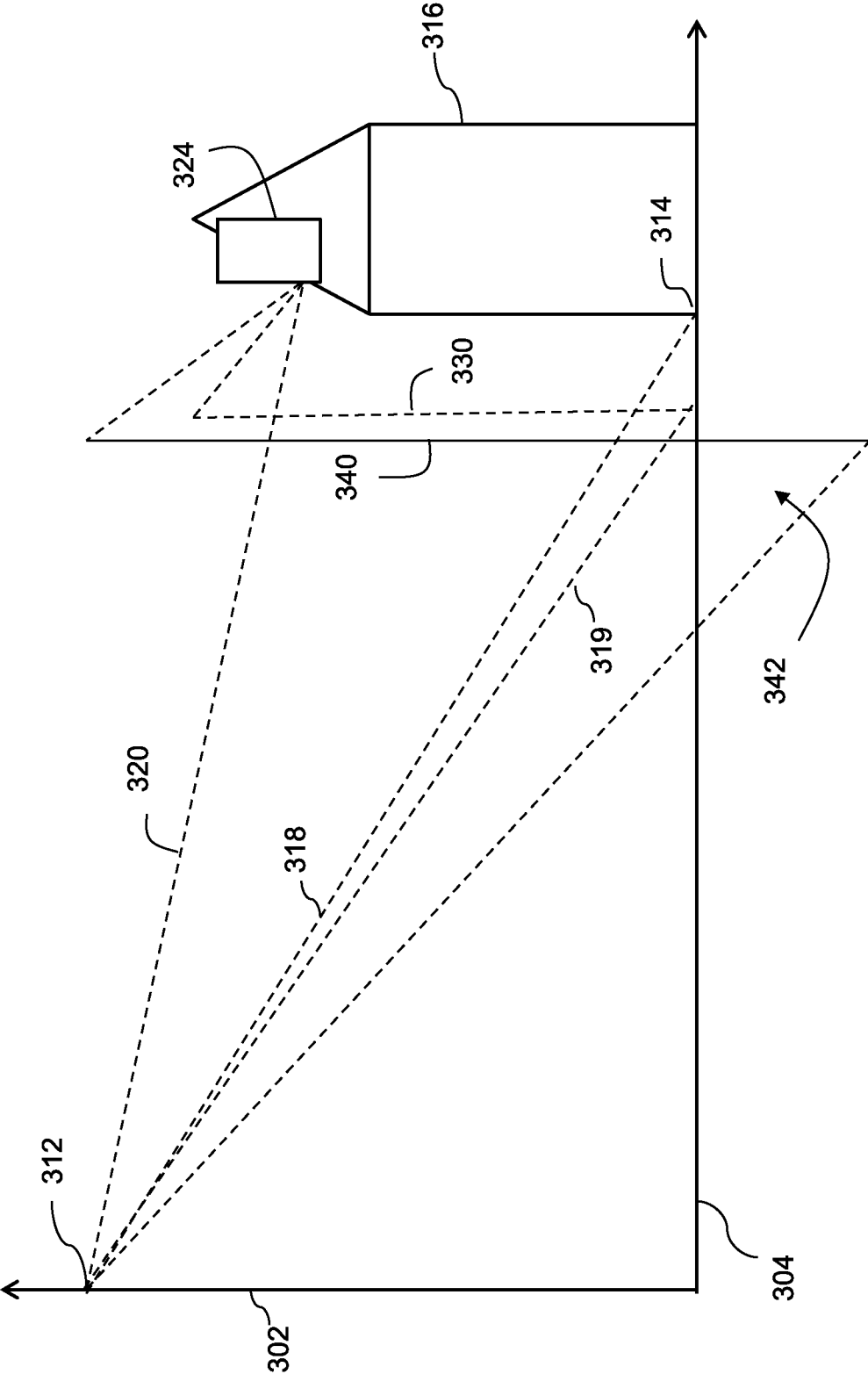


FIG. 3

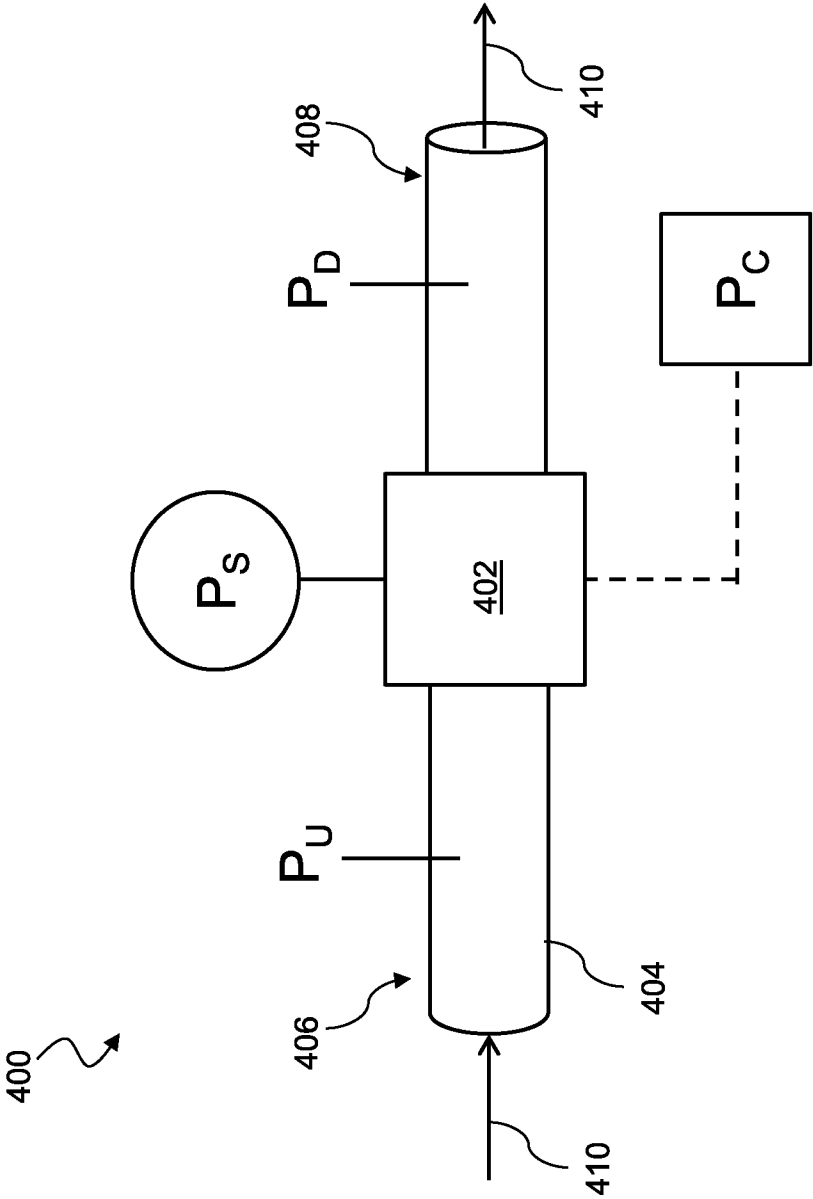
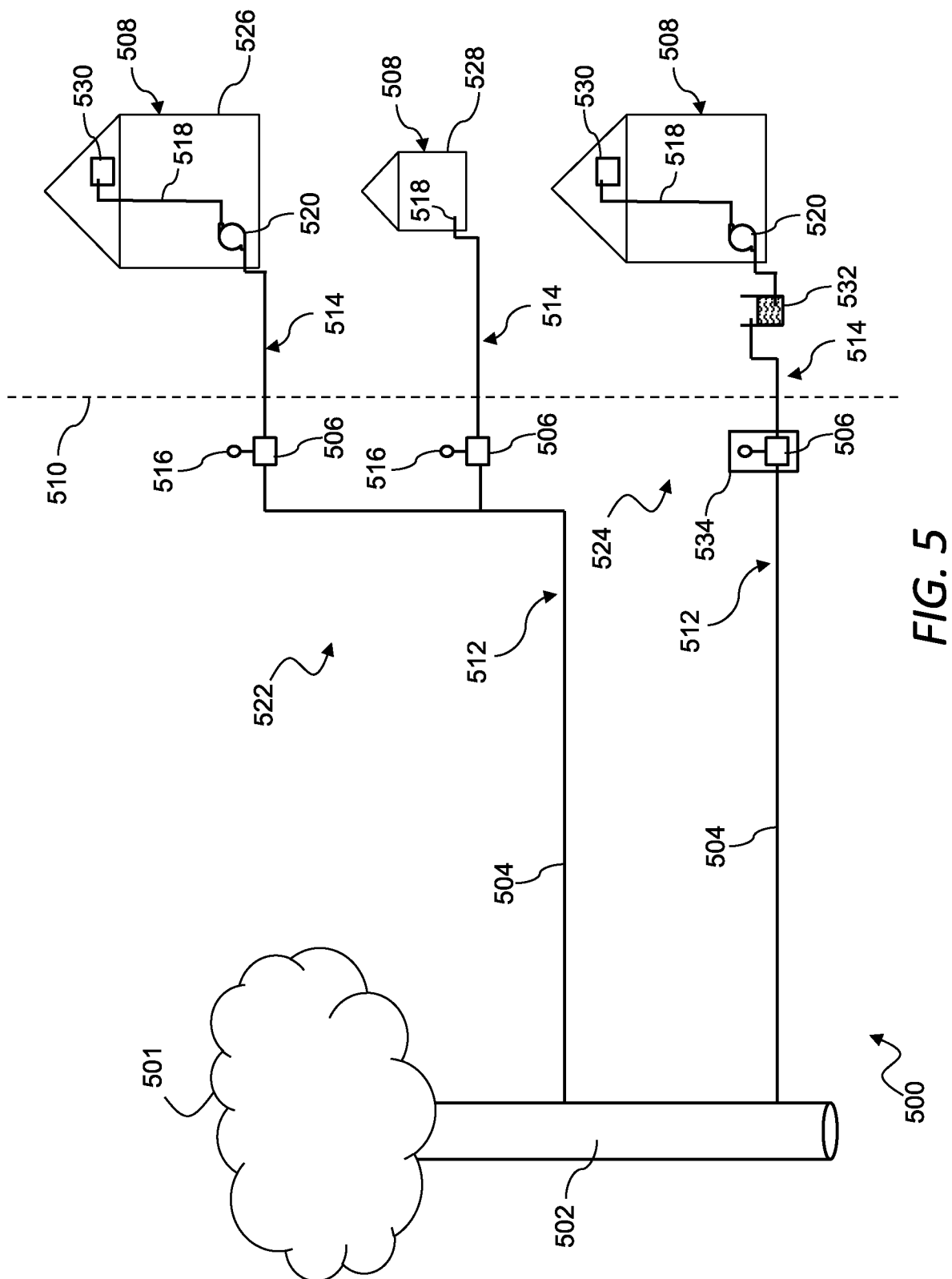


FIG. 4



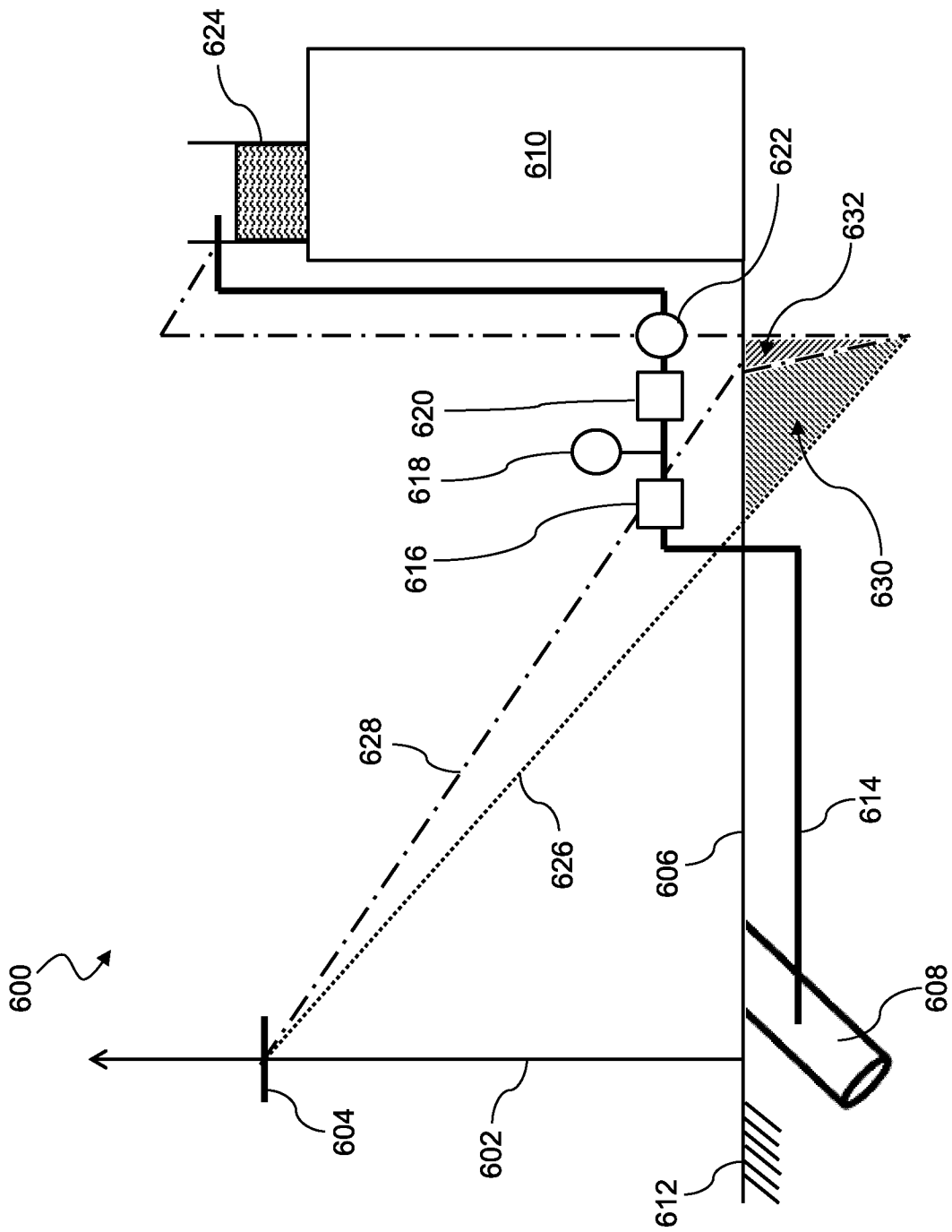


FIG. 6

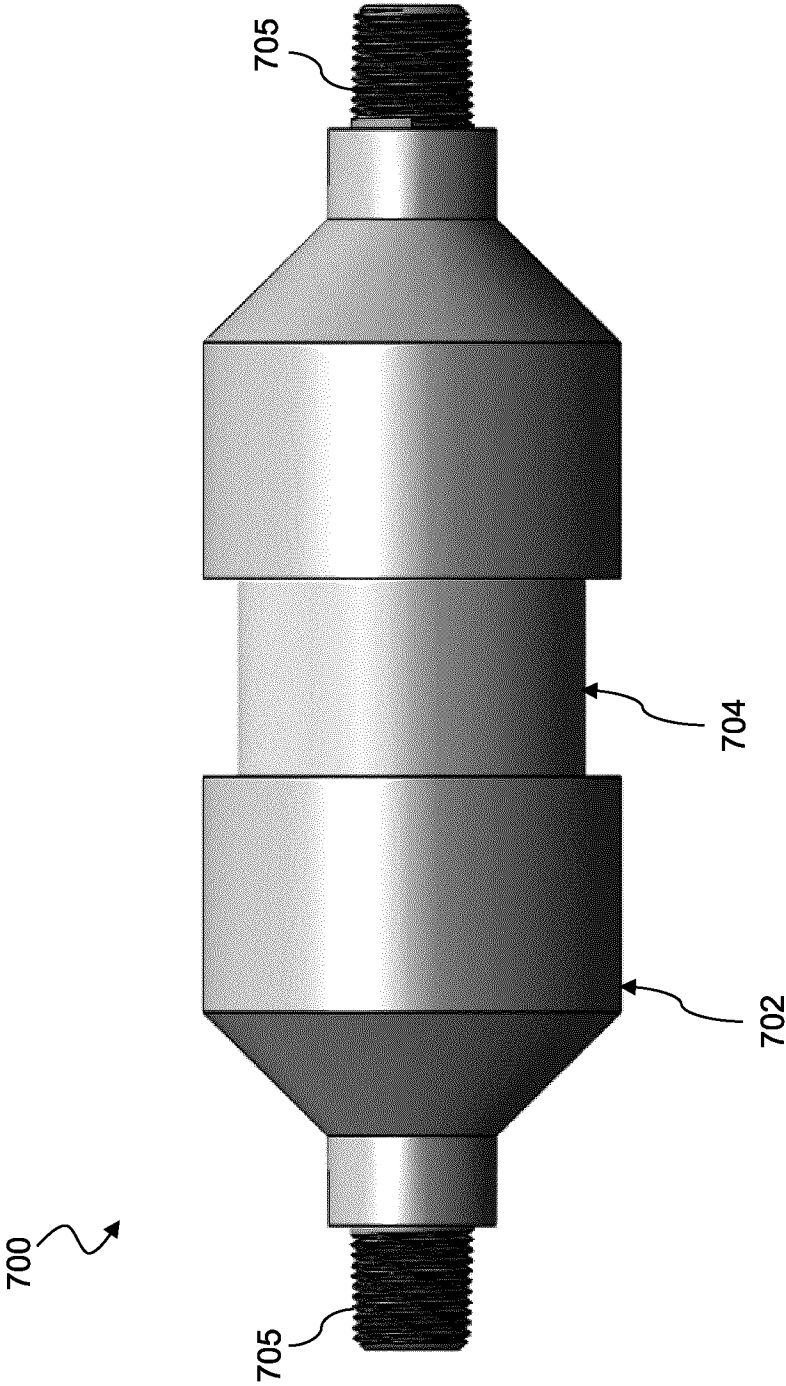


FIG. 7

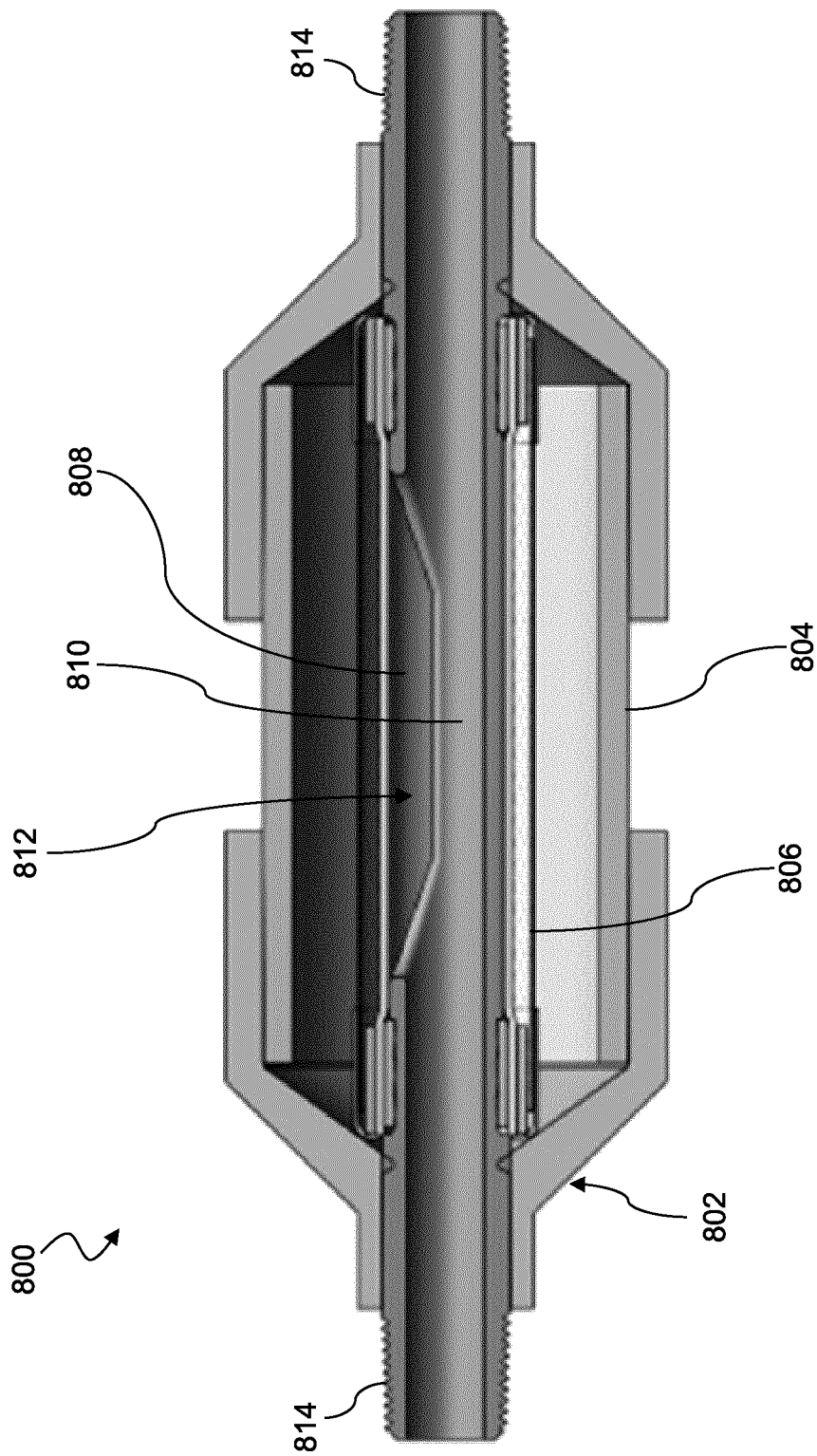


FIG. 8

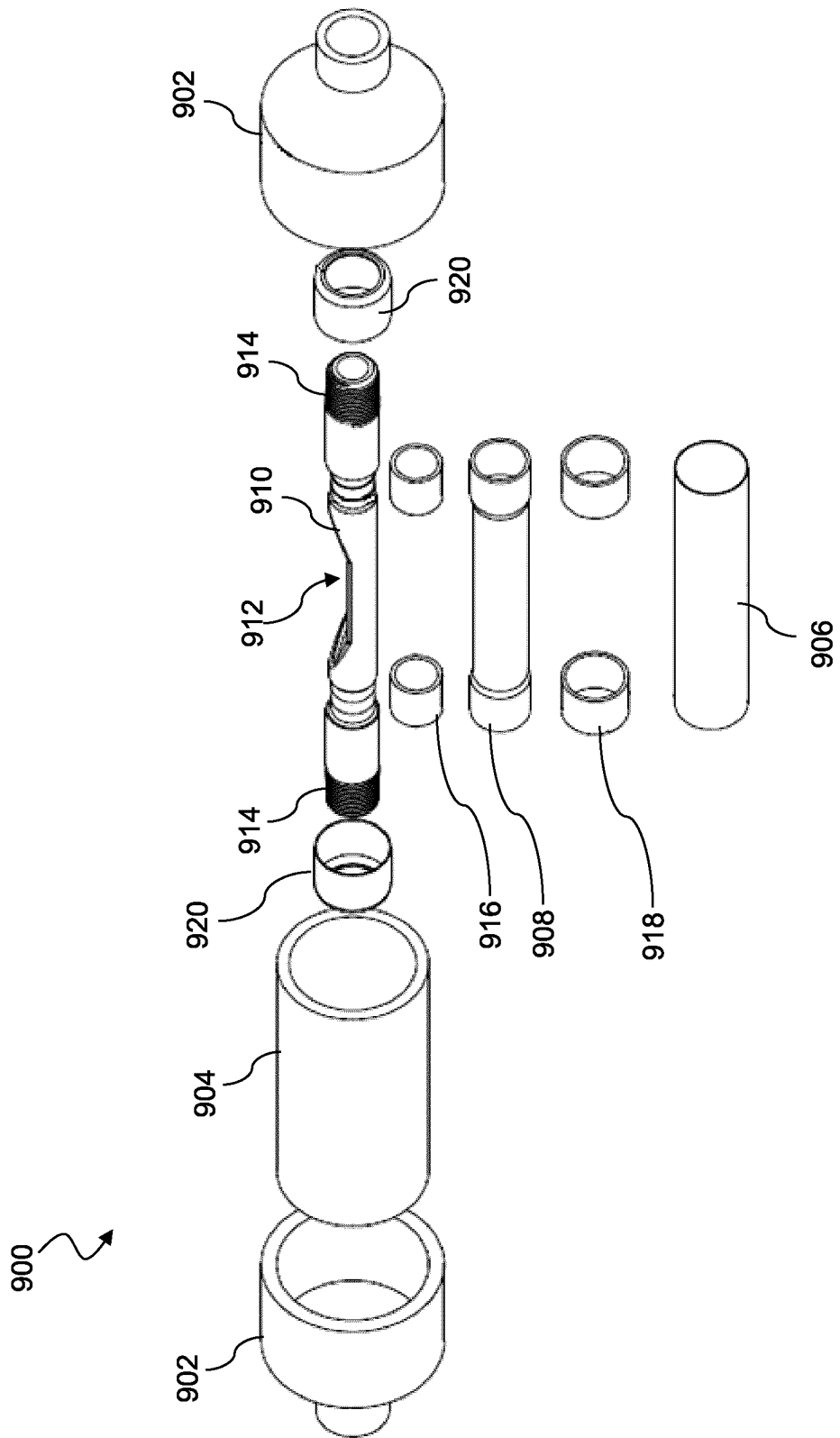


FIG. 9

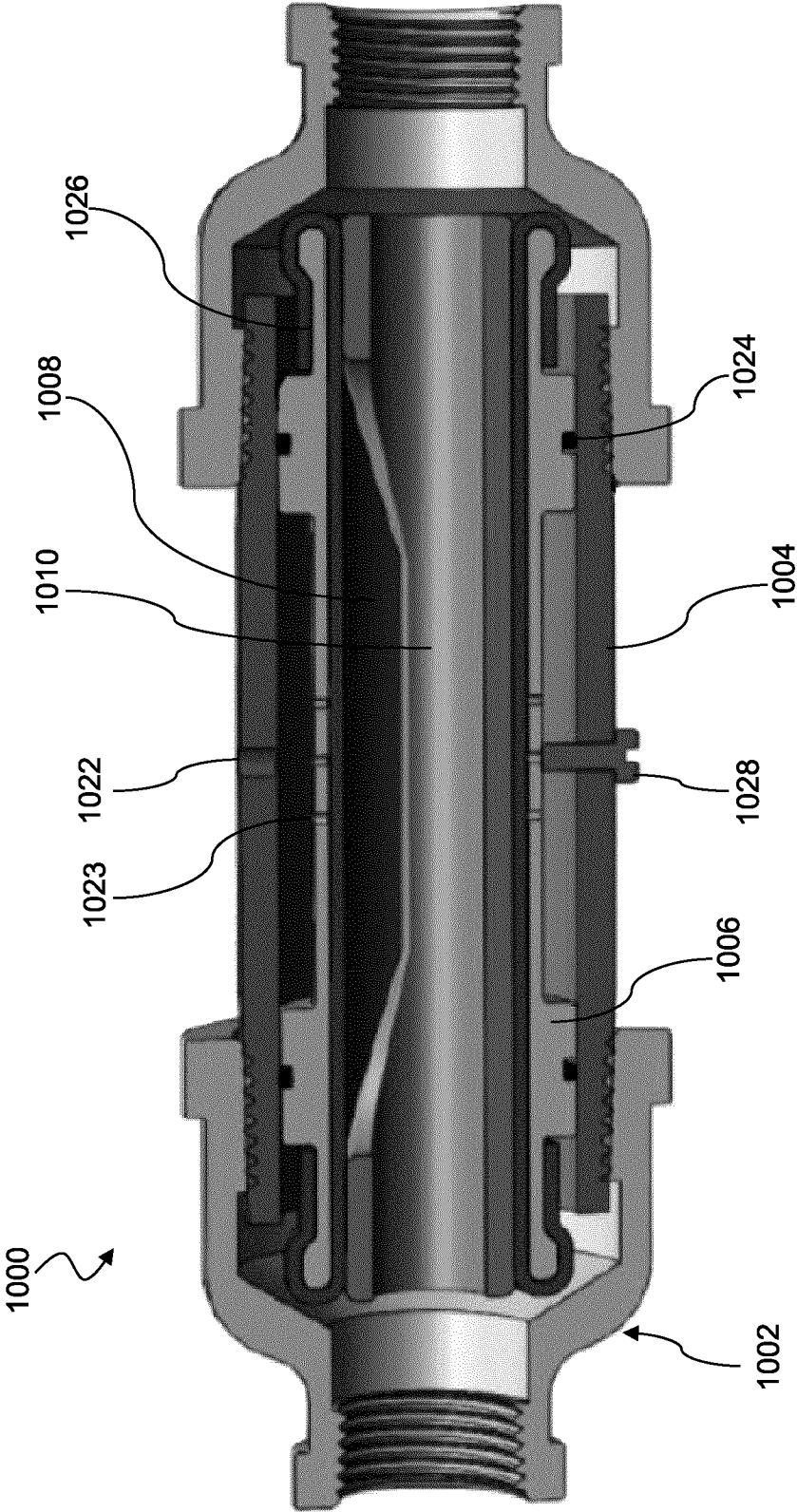


FIG. 10

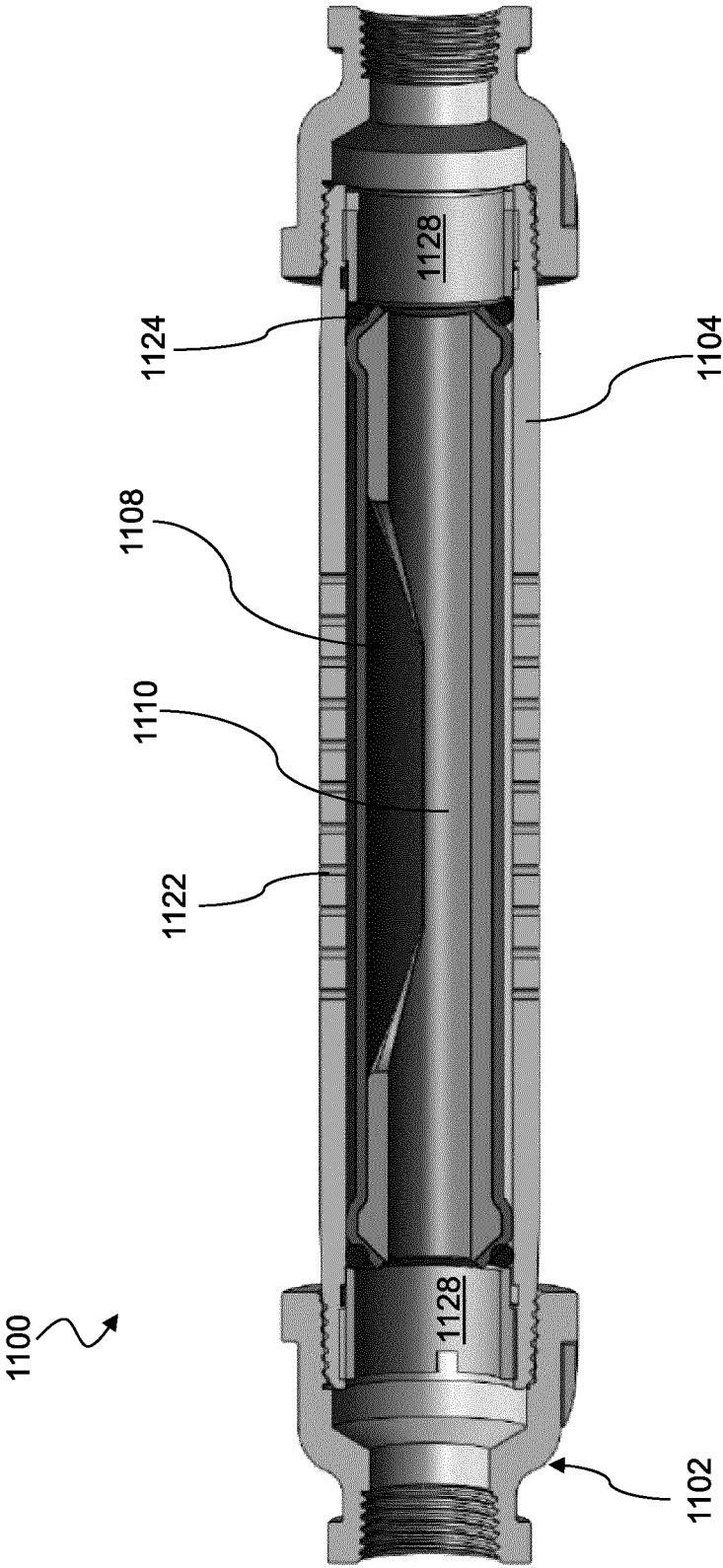
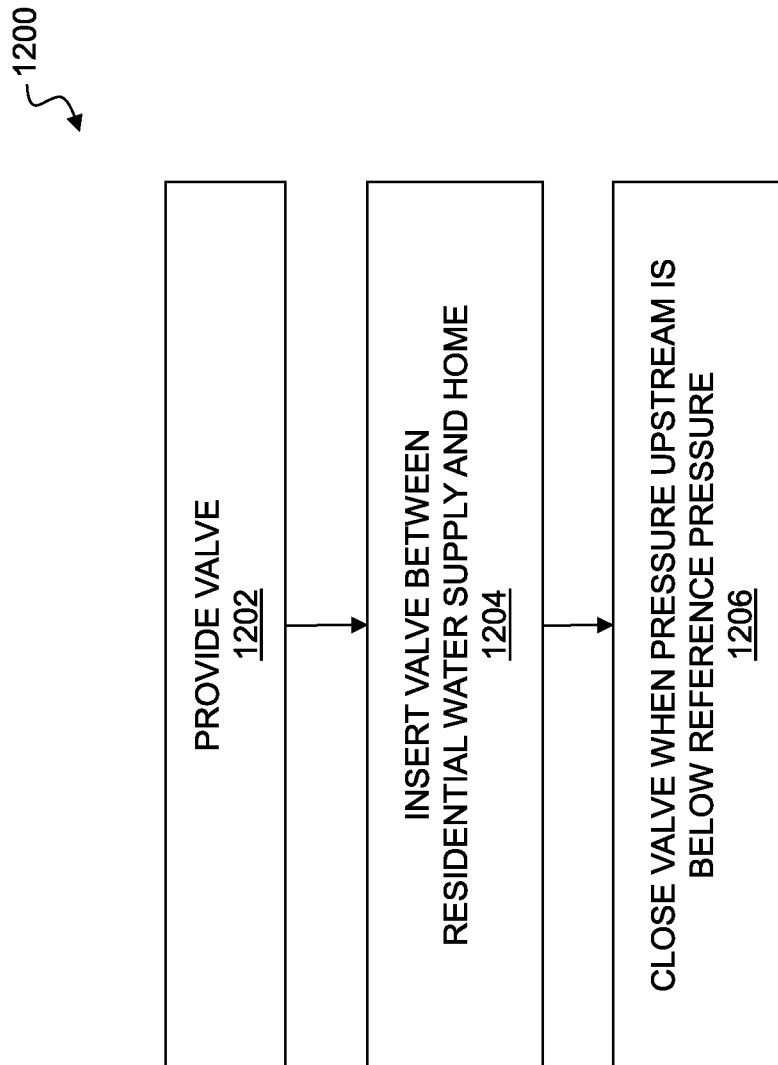


FIG. 11

**FIG. 12**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2015/050002

A. CLASSIFICATION OF SUBJECT MATTER

IPC: **E03B 7/07** (2006.01), **E03B 1/04** (2006.01), **F16K 17/02** (2006.01), **F16K 17/20** (2006.01), **F16K 7/07** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC (2006.01): E03B 7/07, 7/00, 7/02, 7/04; E03B 1/04; F16K 17/02, 17/20, 7/07

CPC: E03B 7/07, 7/075, 7/077

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

LexisNexis TotalPatent (authorities: US, EP, WO, CN, JP, KR, DE, FR, GB, CA, AT, AU, BE, BR, CH, DD, DK, EA, ES, FI, IE, IN, IT, LU, MC, MX, NL, PT, RU, SE, SU, TW – includes search of English machine translations), Google Patents.

Search terms: valve, pump, inlet, upstream, mains, municipal, pressure, regulator, meter, throttle, globe, and pinch.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	CN2668709Y (牟宗华) 05 January 2005 (05-01-2005) *Entire document.*	1 to 3, 5, 7 to 15, and 17 to 20 4, 6, and 16
X Y	CN202117121U (吴卫东) 18 January 2012 (18-01-2012) *Entire document.*	1 to 3, 7 to 15, and 18 to 20 4, 6, and 16
Y	WO2012126287A1 (FEIYU, L. et al.) 27 September 2012 (27-09-2012) *Cover page*	6

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* “A” “E” “L” “O” “P”	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance earlier application or patent but published on or after the international filing date document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) document referring to an oral disclosure, use, exhibition or other means document published prior to the international filing date but later than the priority date claimed	“T” “X” “Y” “&”	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art document member of the same patent family
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Date of the actual completion of the international search
13 March 2015 (13-03-2015)Date of mailing of the international search report
23 March 2015 (23-03-2015)Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 001-819-953-2476

Authorized officer

Javier Jorge (819) 934-2337

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2015/050002

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US2012193559A1 (BENSON, R. et al.) 02 August 2012 (02-08-2012) *Cover page.*	4 and 16
A	WO2009127710A1 (HINES, P. et al.) 22 October 2009 (22-10-2009) *Cover page.*	1 to 20
A	WO2010022442A1 (PORTER-COOTE, R.) 04 March 2010 (04-03-2010) *Cover page.*	1 to 20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CA2015/050002

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
CN2668709Y	05 January 2005 (05-01-2005)	None	
CN202117121U	18 January 2012 (18-01-2012)	None	
WO2012126287A1	27 September 2012 (27-09-2012)	CN102168448A CN102168448B EP2503069A1	31 August 2011 (31-08-2011) 06 February 2013 (06-02-2013) 26 September 2012 (26-09-2012)
US2012193559A1	02 August 2012 (02-08-2012)	US8539827B2 CA2764479A1 MX2012001385A	24 September 2013 (24-09-2013) 31 July 2012 (31-07-2012) 07 August 2012 (07-08-2012)
WO2009127710A1	22 October 2009 (22-10-2009)	EP2288761A1 GB0806976D0 GB2459155A	02 March 2011 (02-03-2011) 21 May 2008 (21-05-2008) 21 October 2009 (21-10-2009)
WO2010022442A1	04 March 2010 (04-03-2010)	AU2008207488A1 AU2009287410A1 EP2324159A1 EP2324159A4 US2011209770A1 US8393352B2	11 March 2010 (11-03-2010) 04 March 2010 (04-03-2010) 25 May 2011 (25-05-2011) 14 November 2012 (14-11-2012) 01 September 2011 (01-09-2011) 12 March 2013 (12-03-2013)