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(54) PRESSURE INDEPENDENT CONTROL VALVE FOR SMALL DIAMETER FLOW, ENERGY USE AND/OR TRANSFER

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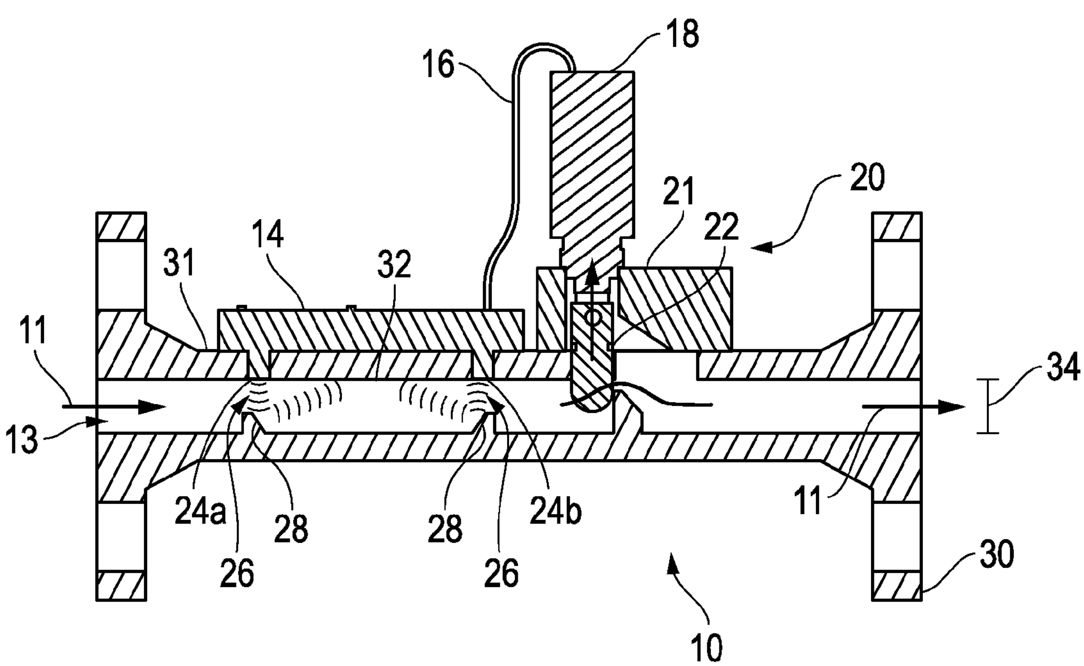
(57) **ABSTRACT**

A pressure independent control valve for small diameter applications for the purpose of regulating or maintaining a predetermined flow rate and/or energy usage/transfer within a pipe system is disclosed. A needle valve is inserted into a flow path where the flow path travels through the needle valve when the needle valve is in an open position. An actuator connects with the needle valve where the actuator is configured to move the needle valve between the open position and a closed position. The flow rate is determined from an ultrasonic sensor positioned in an inner wall of the pipe system or via differential pressure readings. The pipe system has a small diameter.



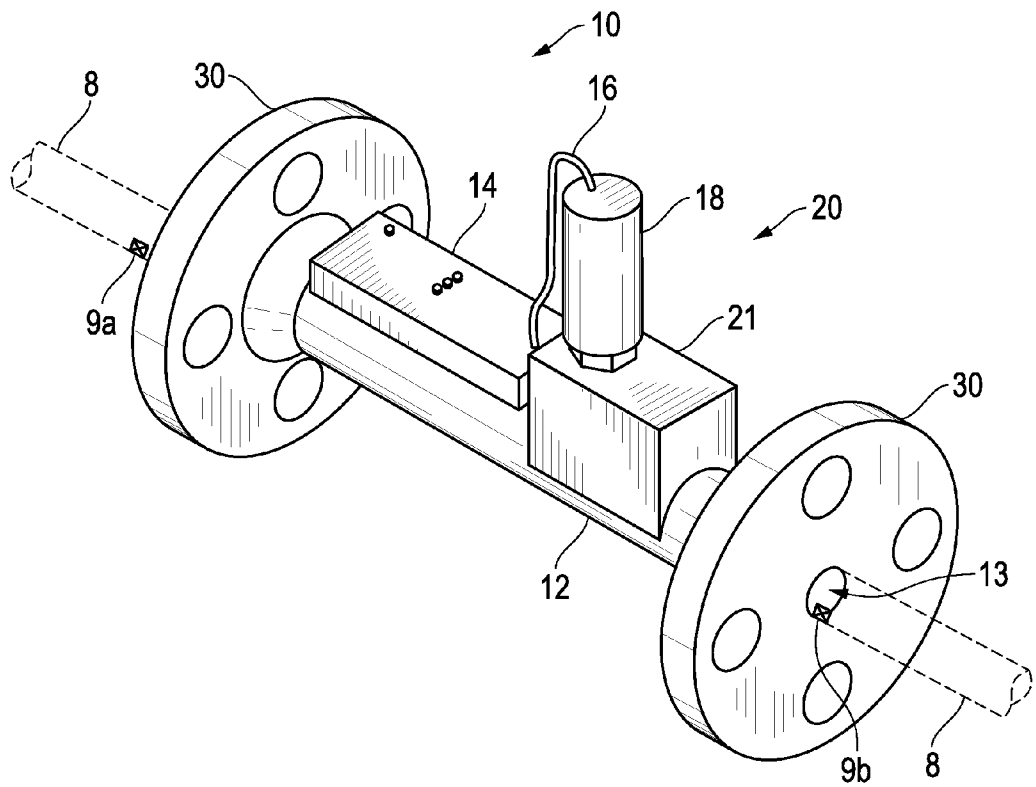
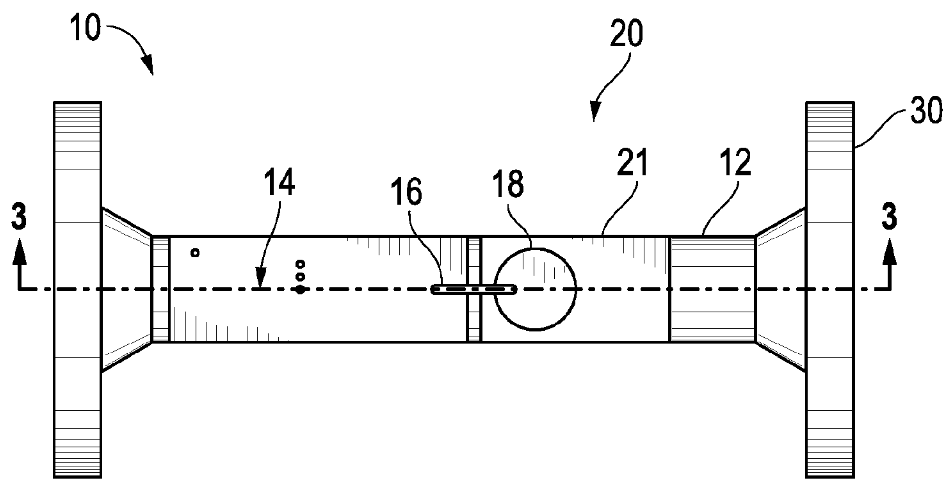


FIG. 1


10
20
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3
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18
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12
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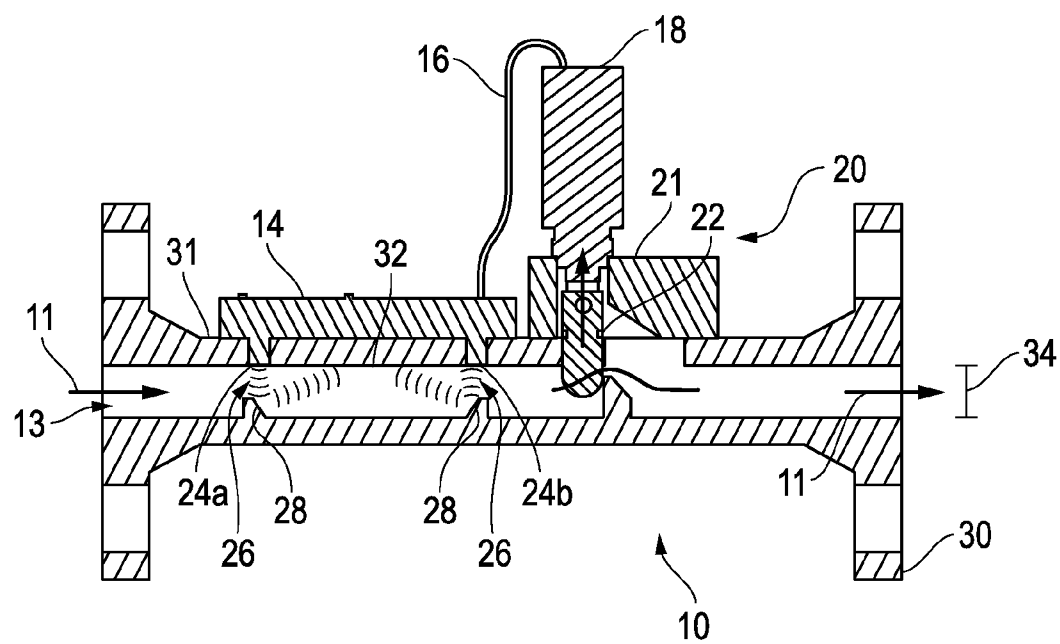
FIG. 2


16
18
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32
31
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34
13
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24a
28
28
24b
26
26
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10

FIG. 3

PRESSURE INDEPENDENT CONTROL VALVE FOR SMALL DIAMETER FLOW, ENERGY USE AND/OR TRANSFER

STATEMENTS REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0001] Not Applicable.

NAMES OF THE PARTIES TO A JOINT RESEARCH AGREEMENT

[0002] Not Applicable.

REFERENCE TO A "SEQUENCE LISTING", A TABLE, OR A COMPUTER PROGRAM

[0003] Not Applicable.

BACKGROUND

Technical Field

[0004] Valve systems are used in heating, ventilation, and air-cooling (HVAC) pipe systems, including in regard to pressure independent control valves used to regulate and maintain the fluid flow rate and/or energy use/transfer of said pipe systems.

[0005] Conventional pressure independent control (PIC) or energy valves rely on the use of magnetic flow meters or sensors. Such systems often have low accuracy levels because magnetism-based sensors can fail to function properly due to debris, metal, or wayward ferrous materials in the pipe system. Further, such systems may rely on the use of valves to modulate the flow of fluid which are expensive to manufacture and thus increases the overall costs of these valve systems. In addition, at certain pipe diameters (for example two-and-a-half inches or smaller), some valves as implemented into prior systems may become prohibitively expensive to produce for a piping system unless purely mechanical designs are implemented.

[0006] Moreover, smaller diameter PIC valves that utilize such a purely mechanical design for low cost suffer limitations in operation and features.

[0007] Thus, a need exists for a low cost, better performing, and higher-accuracy alternative to the traditional small diameter pressure independent control valve systems.

[0008] BRIEF SUMMARY OF THE EMBODIMENTS

[0009] A pressure independent control valve for small diameter applications for the purpose of regulating or maintaining a predetermined flow rate and/or energy usage/transfer within a pipe system is disclosed. A needle valve is inserted into a flow path where the flow path travels through the needle valve when the needle valve is in an open position. An actuator connects with the needle valve where the actuator is configured to move the needle valve between the open position and a closed position. The flow rate is determined from an ultrasonic sensor positioned in an inner wall of the pipe system or via differential pressure readings. The pipe system has a small diameter.

[0010] The phrase 'small diameter' shall mean an internal or flow-way diameter ranging from about 0.5 to 2.5 inches (1.27 centimeters to 6.35 centimeters).

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0011] The embodiments may be better understood, and numerous objects, features, and advantages made apparent to those skilled in the art by referencing the accompanying drawings. These drawings are used to illustrate only typical embodiments of this invention, and are not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments. The figures are not necessarily to scale and certain features and certain views of the figures may be shown exaggerated in scale or in schematic in the interest of clarity and conciseness.

[0012] FIG. **1** depicts a perspective view of one embodiment of a pressure independent control valve system.

[0013] FIG. **2** depicts a top view of one embodiment of a pressure independent control valve system.

[0014] FIG. **3** depicts a cross sectional view of one embodiment of a pressure independent control valve system along line **3-3** of FIG. **2**.

DESCRIPTION OF EMBODIMENT(S)

[0015] The description that follows includes exemplary apparatus, methods, techniques, and instruction sequences that embody techniques of the inventive subject matter. However, it is understood that the described embodiments may be practiced without these specific details.

[0016] FIGS. **1** and **2** depict one embodiment of an improved small diameter pressure independent control valve system **10** in which a flow path **11** runs there through as part of a pipe system **8**. The valve system **10** includes a spool or measurement conduit **12** which defines a flow chamber **13** through which flow path **11** travels into. Spool **12** may have flange connections **30** which connect to the rest of the pipe system **8**. On the downstream end of valve system **10** is needle valve assembly **20**, through which flow path **11** travels past to exit into the remainder of the pipe system **8**. The fluid which travels along flow path **11** may be any type of fluid. For example, the fluid may be any fluid typically used within an HVAC system, including, but not limited to: water, or a water/glycol mixture; or the fluid may be any other type of fluid travelling through a pipe system **8**.

[0017] Moreover, it is critical to the performance of the embodiment(s) described herein that the flow chamber **13** of spool **12** has an internal diameter **34** ranging from 0.5 to 2.5 inches (1.27 centimeters to 6.35 centimeters), i.e. small diameter. The relatively small internal diameter **34** (i.e. selected from a range within 0.5 to 2.5 inches) of the pipe system **8** is a critical factor as it relates to the embodiment(s) described herein because such small diameter systems have a pure mechanical design and/or expensive production costs. The present disclosure features electronic control, higher accuracy flow rate sensing, better performance, and low cost for small diameter pressure independent control valve systems.

[0018] Needle valve assembly **20** and spool **12** may be coupled to the pipe system **8** through flange connections **30**. Needle valve assembly **20** includes a needle valve **22** (which flow path **11** travels there through when the needle valve **22** is in an open position) and a solenoid or small motor **18**. Needle valve assembly **20** may further include a valve housing **21** mounted to the spool **12** to house and stabilize needle valve **22** and/or solenoid or small motor **18**. Although needle valve **22** is actuated by a solenoid or small motor **18**, needle valve **22**

may be actuated by any type of electronic actuator best determined by one of ordinary skill in the art.

[0019] In the embodiment depicted within FIGS. **2-3**, two ultrasonic sensors **24***a* and **24***b* are positioned in the wall **31** of spool **12**, in such manner that transmitted ultrasonic signals **26** from one ultrasonic sensor **24***a* or **24***b* are received by the other respective ultrasonic sensor **24***a* or **24***b*. As depicted in FIG. **3**, the ultrasonic signals **26** are directed towards a reflector **28**, which bounces the ultrasonic signal **26** to the opposite ultrasonic sensor **24***a* or **24***b*. While ultrasonic sensors **24***a* and **24***b* are retained in the wall **31** of spool **12**, ultrasonic sensors **24***a* and **24***b* may alternatively be retained in sensor supports (not illustrated) mounted to the external surface of spool **12**. Further, ultrasonic sensors **24***a* and **24***b* are preferably flush with or slightly recessed into the interior surface **32** of spool **12** so as to not introduce additional disturbance, turbulence or variance into the flow path **11**. Ultrasonic sensors **24***a* and **24***b* are ultrasonic sensors (comprising an ultrasonic flow meter) capable of both transmitting and receiving ultrasonic signals **26** in the form of ultrasonic waves or vibrations across the flow of fluid in flow chamber **13**. Ultrasonic sensors **24***a* and **24***b* may also be positioned at an angle which may be increased or decreased to modify the distance or length traveled by the ultrasonic signal **26** through the fluid medium (the angle can vary depending upon the application e.g.: pipe diameter). Please see U.S. Provisional Patent Application No. 61/881,828 for additional information regarding possible sensor position arrangement, the entire disclosure of which is hereby incorporated by reference.

[0020] Further, ultrasonic sensors **24***a* and **24***b* may deliver data to electronic transducer processor **14** where the data are collected, recorded, compared, and calculated. The ultrasonic sensors **24***a* and **24***b* may communicate the data to electronic transducer processor **14** through wires **16** or other means, or may transmit the data wirelessly.

[0021] The electronic transducer processor **14** itself may be mounted onto the external surface of spool **12** as depicted in FIGS. **1-3**, or may be located elsewhere within the valve system **10** or pipe system **8**. For example, while the figures depict an electronic transducer processor **14** mounted on top of spool **12**, electronic transducer processor **14** may be combined physically with the solenoid or small motor **18**.

[0022] The electronic transducer processor **14** is generally implemented as electronic circuitry and processor-based computational components controlled by computer instructions stored in physical data-storage components, including various types of electronic memory and/or mass-storage devices. It should be noted, at the onset, that computer instructions stored in physical data-storage devices and executed within processors comprise the control components of a wide variety of modern devices, machines, and systems, and are as tangible, physical, and real as any other component of a device, machine, or system. Occasionally, statements are encountered that suggest that computer-instruction-implemented control logic is "merely software" or something abstract and less tangible than physical machine components. Those familiar with modern science and technology understand that this is not the case. Computer instructions executed by processors must be physical entities stored in physical devices. Otherwise, the processors would not be able to access and execute the instructions. The term "software" can be applied to a symbolic representation of a program or routine, such as a printout or displayed list of programming-language statements, but such symbolic representations of computer programs are not executed by processors. Instead, processors fetch and execute computer instructions stored in physical states within physical data-storage devices. Similarly, computer-readable media are physical data-storage media, such as disks, memories, and mass-storage devices that store data in a tangible, physical form that can be subsequently retrieved from the physical data-storage media.

[0023] A desired flow rate or control signal may be input into the electronic transducer processor **14** by an operator of the system, or alternatively, internally set by the manufacturer. When electronic transducer processor **14** determines that the flow rate in flow chamber **13** requires adjustment in order to maintain or modify to the desired flow rate or energy usage/transfer, the electronic transducer processor **14** communicates the necessary correction to solenoid or small motor **18** of the needle valve assembly **20** to change the position of needle valve **22** through wires **16** or wirelessly. The electronic transducer processor **14** may also directly communicate to and/or manipulate the solenoid or small motor **18** to the desired amount of actuation for the necessary movement of the needle valve **22** in order to regulate flow rate or volume. Upon receipt of instructions from electronic transducer processor **14**, the position of needle valve **22** is adjusted accordingly by solenoid or small motor **18** such that the flow rate, flow volume or energy use/transfer is maintained at the predetermined, or set rate.

[0024] In one embodiment, the needle valve **22** spring is biased to a closed position. The electronic transducer processor **14** will manipulate solenoid or small motor **18** by increasing current flow to the solenoid or small motor **18** until the needle valve **22** begins to open. The current is gradually changed/increased until the needle valve **22** reaches an opening which balances the flow detected by the ultrasonic sensors **24***a* and **24***b* to or against the control signal set point. The current to the solenoid or small motor **18** is then increased or decreased to maintain the desired flow.

[0025] In an alternate embodiment, the needle valve **22** spring is biased to an open position. The electronic transducer processor **14** will manipulate solenoid or small motor **18** by changing/decreasing current flow to the solenoid or small motor **18** until the needle valve **22** begins to close. The current is gradually decreased until the needle valve **22** reaches a position which balances the flow detected by the ultrasonic sensors **24***a* and **24***b* to or against the control signal set point. The current to the solenoid or small motor **18** is then increased or decreased to maintain the desired flow.

[0026] To calculate the flow of fluid in the pipe system **8**, the ultrasonic sensor **24***a* transmits an ultrasonic signal **26** across the flow path **11** to reflector **28**. The reflector **28** reflects the ultrasonic signal **26** at an angle across flow path **11** to ultrasonic sensor **24***b*, which receives the ultrasonic signal **26**. The period of time taken by ultrasonic signal **26** to reach ultrasonic sensor **24***a* or **24***b* is affected by the velocity of the fluid in flow path **11**. The ultrasonic sensor **24***b* records the time at which the ultrasonic signal **26** is received and may also transmit an ultrasonic signal **26** back to ultrasonic sensor **24***a*. Ultrasonic sensor **24***a* also records the time at which any second ultrasonic signal **26** is received, and may transmit another ultrasonic signal **26** to ultrasonic sensor **24***b*. The back-and-forth transmittal and receipt process between the ultrasonic sensors **24***a* and **24***b* is continuously, periodically, or intermittently conducted, as desired, while the flow of the pipe system **8** is to be monitored and maintained at a predetermined or preferred flow rate as entered into electronic transducer processor **14**. The data regarding the recorded times of transmission and receipt of the ultrasonic signals **26** of the valve system **10** are used to calculate the flow rate of the fluid in the flow chamber **13**.

[0027] The ultrasonic sensors **24***a* and **24***b* return sensor output, or feedback, to the electronic transducer processor **14** through wires **16** or wireless communication. Based on this feedback, the electronic transducer processor **14** modifies the output control commands in order to achieve the specified flow rate or energy usage for the valve system **10**.

[0028] In another embodiment to calculate the flow of fluid in the pipe system **8** (instead of or in addition to the ultrasonic sensors **24***a*, **24***b*), an inlet pressure sensor **9***a* and an outlet pressure sensor **9***b* may be used to measure or detect the differential pressure at the inlet and the outlet of the small diameter pressure independent control valve system **10**. The differential flow may then be characterized and used to derive or determine the flow rate of the fluid in the pipe system **8**.

[0029] While the embodiments are described with reference to various implementations and exploitations, it will be understood that these embodiments are illustrative and that the scope of the inventive subject matter is not limited to them. Many variations, modifications, additions and improvements are possible. For example, the techniques used herein may be applied to any valve system or assembly used for piping systems.

[0030] Plural instances may be provided for components, operations or structures described herein as a single instance. In general, structures and functionality presented as separate components in the exemplary configurations may be implemented as a combined structure or component. Similarly, structures and functionality presented as a single component may be implemented as separate components. These and other variations, modifications, additions, and improvements may fall within the scope of the inventive subject matter.

1. An apparatus for maintaining a desired flow rate in a flow path within a pipe system, comprising:

a needle valve inserted into the flow path, wherein the flow path travels through the needle valve when the needle valve is in an open position;

an actuator in connection with the needle valve, wherein the actuator is configured to move the needle valve between the open position and a closed position;

a sensor selected from the group of sensors consisting of an ultrasonic sensor positioned in an inner wall of the pipe system wherein the ultrasonic sensor is configured to transmit and receive an ultrasonic signal, and an inlet pressure senor positioned proximate an inlet end of the pipe system and an outlet pressure sensor positioned downstream from the inlet pressure sensor; and

wherein the pipe system has a small diameter.

2. The apparatus of claim **1**, further comprising a reflector mounted on the inner wall of the pipe system, wherein the reflector is configured to reflect the ultrasonic signal.

3. The apparatus of claim **1**, wherein the actuator is an electronic actuator.

4. The apparatus of claim **3**, wherein the actuator is a solenoid.

5. The apparatus of claim **4**, further comprising an electronic transducer processor in data communication with the solenoid and the ultrasonic sensor.

6. The apparatus of claim **5**, further comprising wires connecting the electronic transducer processor to the actuator.

7. The apparatus of claim **5**, wherein the electronic transducer processor includes a data storage device.

8. The apparatus of claim **1**, wherein the ultrasonic sensor is positioned at an angle to the flow path.

9. The apparatus of claim **1**, wherein the needle valve is biased to the closed position.

10. The apparatus of claim **1**, wherein the needle valve is biased to the open position.

11. A pressure independent control valve system, comprising:

a spool located within the valve system, having an inner diameter which defines a flow path having a small diameter;

a needle valve mounted to the spool, wherein the needle valve is configured to alter a flow rate when the needle valve is between an open position and a closed position of the needle valve;

an actuator configured to manipulate the needle valve between the open position and the closed position;

a sensor selected from the group of sensors consisting of an ultrasonic sensor mounted to an inner wall of the spool wherein the ultrasonic sensor is mounted in a position to transmit and receive an ultrasonic signal across the flow path; and an inlet pressure senor positioned proximate an inlet end of the pipe system and an outlet pressure sensor positioned downstream from the inlet pressure sensor;

a reflector mounted to the inner wall of the spool, wherein the reflector is mounted in such a position to reflect the ultrasonic signal to a second ultrasonic sensor; and

an electronic transducer processor in data communication with the actuator and the ultrasonic sensors.

12. A method for maintaining the flow rate in a pressure independent control valve system, comprising the steps of:

setting a desired flow rate into an electronic transducer processor;

supplying a flow of fluid into a flow chamber within the valve system, wherein the flow chamber has a small diameter;

transmitting an ultrasonic signal across the flow chamber, wherein the ultrasonic signal is transmitted by an ultrasonic sensor;

reflecting the ultrasonic signal;

receiving the ultrasonic signal with a second ultrasonic sensor;

determining a period of time for between the transmittal and the receipt of the ultrasonic signal;

calculating a present flow rate based on the period of time;

comparing the present flow rate to the desired flow rate; and

adjusting a position of a needle valve inserted into the flow of fluid to obtain the desired flow rate.

13. The method according to claim **12**, further comprising the step of storing the desired flow rate and the present flow rate into a data storage device in communication with the electronic transducer processor.

14. The method according to claim **13**, wherein the step of adjusting the position of the needle valve comprises actuating the needle valve with a solenoid actuator.

15. The method according to claim **14**, wherein the step of adjusting the position of the needle valve further comprises changing a current flow to the solenoid actuator.

16. The method according to claim **15**, further comprising the step of repeating the steps of:

transmitting an ultrasonic signal across the flow chamber, wherein the ultrasonic signal is transmitted by an ultrasonic sensor;

reflecting the ultrasonic signal;

receiving the ultrasonic signal with a second ultrasonic sensor;

determining a period of time for between the transmittal and the receipt of the ultrasonic signal; and

calculating a present flow rate based on the period of time.

17. The method according to claim **16**, further comprising the steps of:

collecting a record of the calculated present flow rates based on the repetition; and

storing the record.

18. The method according to claim **17**, further comprising the step of modifying the desired flow rate based on the stored record.

19. The method according to claim **18**, further comprising the step of initially biasing the needle valve to an open position.

20. The method according to claim **18**, further comprising the step of initially biasing the needle valve to a closed position.

21. The method according to claim **12** including using an inlet pressure senor positioned proximate an inlet end of a pipe system and an outlet pressure sensor positioned downstream from the inlet pressure sensor instead of or in addition to the ultrasonic sensors for detecting a differential pressure; and characterizing the flow rate of fluid in the pipe system for calculating the present flow rate.

* * * * *