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(71) Applicant: **SAUDI ARABIAN OIL COMPANY**
[SA/SA]; 1 Eastern Avenue, Dhahran, 31311 (SA).

(71) Applicant (for AG only): **ARAMCO SERVICES COMPANY** [US/US]; 1200 Smith Street, Two Allen Building, Houston, Texas 77002 (US).

(72) Inventors: **AL-JINDAN, Jana M.**; Saudi Aramco, P.O. Box. 11052, Dhahran, 31311 (SA). **NOUI-MEHIDI, Mohamed Nabil**; Saudi Aramco, P.O. Box 10845, Dhahran, 31311 (SA).

(74) Agent: **BRUCE, Carl E.** et al.; FISH & RICHARDSON P.C., P.O. Box 1022, Minneapolis, Minnesota 55440-1022 (US).

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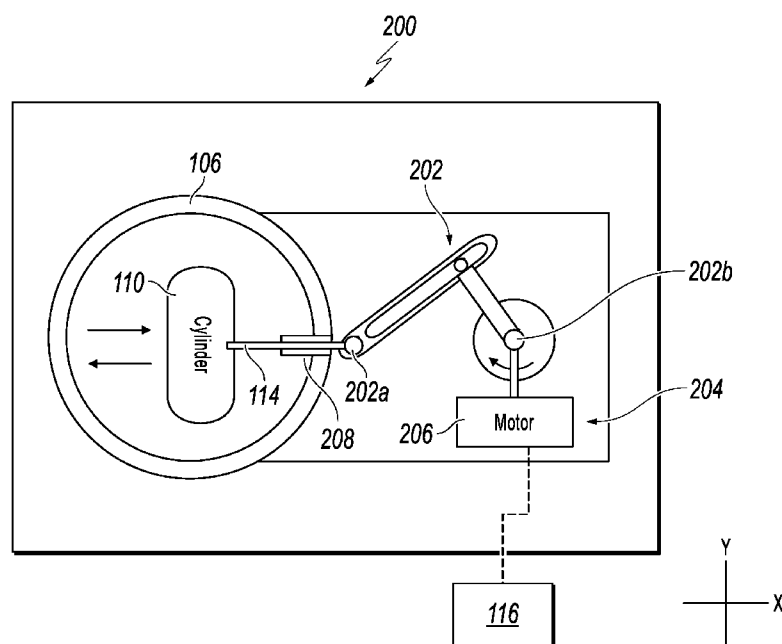


FIG. 2

(57) **Abstract:** A vortex flow meter is within a flow conduit. The vortex flow meter includes a housing defining a flow passage substantially in-line with the flow conduit. An actuable buff body is within the flow passage. A sensor is downstream of the actuable buff body and is attached to the housing. The sensor is configured to detect vortex shedding. A controller is configured to send a drive signal to an oscillator to oscillate the buff body. The controller is configured to receive a vortex stream from the sensor. The vortex stream is indicative of vortices shed by the buff body within a fluid. The controller is configured to determine a flow velocity responsive to the received vortex stream.



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REDUCING NOISE IN A VORTEX FLOW METER

CLAIM OF PRIORITY

[0001] This application claims priority to U.S. Patent Application No. 16/921,104 filed on July 6, 2020, the entire contents of which are hereby incorporated
5 by reference.

TECHNICAL FIELD

[0002] This disclosure relates to flow meters.

BACKGROUND

[0003] Vortex shedding flow meters use the phenomenon known as Von
10 Karman vortices, which are alternating vortices that form behind a fixed bluff body such as a circular cylinder. The frequency of the vortex shedding, that is, the time period between two successive vortices, is proportional to the flow rate for fixed dynamical, geometrical, and physical properties of the flow system. The shedding frequency is measured by several means, such as ultrasonic transducers or pressure
15 gauges.

SUMMARY

[0004] This disclosure describes technologies relating to reducing noise in a vortex flow meter.

[0005] An example implementation of the subject matter described within this
20 disclosure is a vortex flow meter with the following features. A housing defines a flow passage. An actuable bluff body is within the flow passage. A sensor is downstream of the actuable bluff body and is attached to the housing. The sensor is configured to detect vortex shedding in a fluid flowing past the bluff body.

[0006] Aspects of the example vortex flow meter, which can be combined with
25 the example flow meter alone or in part, include the following. A linkage is attached to the bluff body at a first end of the linkage. An actuator is attached to a second end of the linkage. The actuator is configured to oscillate the actuable bluff body.

[0007] Aspects of the example vortex flow meter, which can be combined with
the example flow meter alone or in part, include the following. The linkage includes a
30 cable.

[0008] Aspects of the example vortex flow meter, which can be combined with the example flow meter alone or in part, include the following. The actuator includes an electric motor or a piezoelectric material.

5 [0009] Aspects of the example vortex flow meter, which can be combined with the example flow meter alone or in part, include the following. The sensor includes an acoustic sensor.

[0010] Aspects of the example vortex flow meter, which can be combined with the example flow meter alone or in part, include the following. The buff body is configured to oscillate with an amplitude of up to 10 millimeters.

10 [0011] Aspects of the example vortex flow meter, which can be combined with the example flow meter alone or in part, include the following. The buff body is configured to oscillate between 0.03 hertz and 0.045 hertz.

[0012] Aspects of the example vortex flow meter, which can be combined with the example flow meter alone or in part, include the following. A controller is configured to send a drive signal to an oscillator to oscillate the buff body. The controller is configured to receive a vortex stream from the sensor, the vortex stream indicative of vortices shed by the buff body within a fluid. The controller is configured to determine a flow velocity responsive to the received vortex stream.

15 [0013] Aspects of the example vortex flow meter, which can be combined with the example flow meter alone or in part, include the following. The vortex stream includes an analog signal.

[0014] Aspects of the example vortex flow meter, which can be combined with the example flow meter alone or in part, include the following. The controller is further configured to adjust an amplitude of oscillations in response to adjusting operation conditions, and adjust a frequency in response to adjusting operation conditions.

[0015] Aspects of the example vortex flow meter, which can be combined with the example flow meter alone or in part, include the following. The buff body is cylindrical and perpendicular to the flow passage.

20 [0016] An example of the subject matter described within this disclosure is a method with the following features. A fluid flow is received by a conduit. The fluid flow is flowed over a buff body within the conduit. The buff body, positioned within the conduit, within the fluid flow, is oscillated. Vortex shedding is produced by

the buff body responsive to flowing the fluid flow over the buff body. The vortex shedding is sensed by a sensor downstream of the buff body within the conduit. A vortex stream is produced by the sensor responsive to sensing the vortex shedding by the sensor. The vortex stream is indicative of vortices shed by the buff body within the fluid. The vortex stream is received by a controller. A flow velocity is determined by the controller responsive to the received vortex stream.

[0017] Aspects of the example method, which can be combined with the example method alone or in part, include the following. Oscillating the buff body includes oscillating the buff body with an amplitude of up to 10 mm.

[0018] Aspects of the example method, which can be combined with the example method alone or in part, include the following. Oscillating the buff body includes to oscillating the buff body between 0.03 hertz and 0.045 hertz.

[0019] Aspects of the example method, which can be combined with the example method alone or in part, include the following. Oscillating the buff body includes adjusting an amplitude of oscillations in response to adjusting operation conditions of the fluid flow and adjusting a frequency in response to adjusting operation conditions.

[0020] Aspects of the example method, which can be combined with the example method alone or in part, include the following. Oscillating the buff body includes rotating linkage, connected at a first end of the linkage to the buff body, by motor attached to a second end of the linkage.

[0021] Aspects of the example method, which can be combined with the example method alone or in part, include the following. Oscillating the buff body includes linearly translating the buff body by cable.

[0022] Aspects of the example method, which can be combined with the example method alone or in part, include the following. Oscillating the buff body includes directing a current into a piezoelectric material coupled to the buff body.

[0023] An example of the subject matter described within this disclosure is a system with the following features. A vortex flow meter is within a flow conduit. The vortex flow meter includes a housing defining a flow passage substantially in-line with the flow conduit. An actuable buff body is within the flow passage. A sensor is downstream of the actuable buff body and is attached to the housing. The sensor is configured to detect vortex shedding. A controller is configured to send a drive signal

to an oscillator to oscillate the buff body. The controller is configured to receive a vortex stream from the sensor. The vortex stream is indicative of vortices shed by the buff body within a fluid. The controller is configured to determine a flow velocity responsive to the received vortex stream.

5 [0024] Aspects of the example system, which can be combined with the example system alone or in part, include the following. The vortex flow meter is at least twelve conduit diameters in length from any bends in the conduit.

[0025] Aspects of the example system, which can be combined with the example system alone or in part, include the following. The controller is further
10 configured to adjust an amplitude of oscillations in response to adjusting operation conditions of the fluid flow, and adjust a frequency in response to adjusting operation conditions of the fluid flow.

[0026] The details of one or more implementations of the subject matter described in this disclosure are set forth in the accompanying drawings and the
15 description below. Other features, aspects, and advantages of the subject matter will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] FIG. 1 is a cross-sectional view of an example vortex flow meter installed within a fluid conduit.

20 [0028] FIG. 2 is a planar cross-sectional view of an example buff body actuation system that can be used with the example vortex flow meter.

[0029] FIG. 3 is a planar cross-sectional view of an example buff body actuation system that can be used with the example vortex flow meter.

[0030] FIG. 4 is a planar cross-sectional view of an example buff body
25 actuation system that can be used with the example vortex flow meter.

[0031] FIG. 5 is a block diagram of an example controller that can be used within the context of this disclosure.

[0032] FIG. 6 is a flowchart of an example method that can be used in the context of this disclosure.

30 [0033] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0034] This disclosure relates to improving a signal-to-noise ratio of a vortex meter through mechanical oscillation of the buff body. The mechanical oscillation increases the amplitude of measured Von Karman vortices to be higher than the amplitude of the process noise occurring through the process line, thereby increasing the signal-to-noise ratio of the measurements. Three specific implementations are described: a linear mechanical implementation with rigid members, a linear mechanical implementation with cable or belts, and a piezoelectric implementation. Such implementations can ensure that the shedding frequency of the vortexes is not buried in the process noise when flow rate measurements are performed.

[0035] FIG. 1 is a cross-sectional view of a system 100 with an example vortex flow meter 102 installed within a fluid conduit 104. The vortex flow meter 102 defines a flow passage with the flow conduit 104. The vortex flow meter 102 includes a housing 106 defining the flow passage 108 substantially in-line with the flow conduit 104. That is, the central axis of the flow passage 108 and the flow conduit 104 substantially align with one another within standard manufacturing tolerances. Within the flow passage 108 is an actuable buff body 110 coupled to the vortex flow meter 102 by a support 114. In the context of this disclosure, “actuable” is used to describe an object that can be actively moved by an outside force, such as that provided by an actuator or motor. The support is rigidly coupled to the buff body and is axially coupled to an actuator (not shown) that allows freedom of movement for both the buff body 110 and the support 114 itself relative to the housing 106. Structural details that allow for such freedom of movement are discussed throughout this disclosure. In general, vortex flow meters work best with smooth, unimpeded flow. As such, vortex flow meters, such as vortex flow meter 102, are often installed at least twelve conduit diameters in length from any bends in the conduit 104.

[0036] In the context of this disclosure, “upstream” and “downstream” are used to describe positions of various objects relative to the flow direction of fluid flowing through the conduit. For example, the flow through the illustrated implementation shows fluid passing first past the buff body 110, then in a direction towards a sensor 112. As the sensor 112 is in the direction of flow in relation to the buff body 110, the sensor is downstream of the buff body 110. Conversely, the buff body is against the

direction of flow in relation to the sensor, so the buff body 110 is upstream of the sensor 112.

[0037] In the illustrated implementation, the buff body 110 is cylindrical and perpendicular to the flow passage; however, other shapes and orientations can be used without departing from this disclosure. For example, an airfoil shaped buff body can be used. In general, the buff body 110 is a substantially rigid object that can be made of any inert material suitable for the process conditions. For example, metal or an elastomer can be used. The buff body 110 itself can be solid or hollow depending upon the requirements based on the process conditions within the fluid flow. The buff body 110 itself is configured to be linearly oscillated perpendicular to the fluid flow and parallel to a support 114. As illustrated in FIG. 1, the fluid flow flows along the X-axis and the buff body 110 oscillates along the Y-axis. Depending on the geometry of the conduit 104, flow rate, flow density, and other factors, the amplitude and the frequency of the buff body oscillations can be varied. For example, in some implementations, the buff body 110 is configured to oscillate with an amplitude of up to 10 millimeters. For example, in some implementations, the buff body 110 is configured to oscillate between 0.03 hertz and 0.045 hertz. Other oscillation amplitudes and frequencies can be used depending upon the flow conditions within the conduit 104.

[0038] A sensor 112 is positioned downstream of the actuable buff body 110 and attached to the housing 106. For example, the sensor can be placed five to ten conduit diameters of equivalent length downstream of the buff body 110. The sensor 112 is configured to detect vortex shedding. Several different types of sensors can be used to detect vortex shedding, for example, an acoustic sensor or a pressure sensor. In some implementations using an acoustic sensor, the acoustic sensor includes an acoustic emitter on one side of the conduit 104 and an acoustic receiver on an opposite side of the conduit 104. The acoustic emitter transmits acoustic waves to the acoustic receiver, and the time delay, signal attenuation, or both, is measured. In some implementations, an acoustic receiver can be used without an emitter if fluid properties, such as density, are known. In implementations that use a pressure sensor, the pressure within the conduit will vary over time at the sensor location downstream of the buff body 110. This variance can be detected and analyzed as the variance is indicative of vortex shedding.

[0039] A controller 116 is coupled to the vortex flow meter 102 and the sensor 112. The controller 116 is configured to send a drive signal to an oscillator (described later) to oscillate the buff body 110 and receive a vortex stream from the sensor 112. The vortex stream is a signal indicative of vortices shed by the buff body within a fluid. The vortex stream can be an analog or digital signal produced or modified by the sensor 112. The controller 116 receives the vortex stream and determines a flow velocity responsive to receiving the vortex stream. Further details of the example controller 116 are described later within this disclosure.

[0040] FIG. 2 is a planar cross-sectional view of an example buff body actuation system 200 that can be used with the example vortex flow meter 102. The actuation system 200 includes a linkage 202 attached to the buff body 110 or buff body support 114 at a first end 202a of the linkage 202 and an actuator 204 attached to a second end 202b of the linkage 202. Typically, the actuator 204 is located outside the housing so as to not interfere with the fluid flow; however, other arrangements can be conceived without departing from this disclosure. The actuator 204 is configured to oscillate the actuable buff body 110 and support 114 relative to the housing by transferring motion through the linkage 202. In the illustrated implementation, the actuator 204 includes an electric rotary motor 206. Alternatively or in addition, linear motors or solenoids can be used to actuate the buff body 110. Alternatively or in addition, hydraulic actuators, motors, or both can be used to actuate the buff body 110. While the illustrated implementation shows a two-part linkage 202 configured to translate rotational motion into linear motion, other linkage configurations can be used without departing from this disclosure. In some implementations, a seal 208 encircles the support 114 or linkage 202 to fluidically isolate the linkage 202 and actuator 204 from the fluid flow. In some implementations, the actuation system 200 can be configured to operate in a wetted state. That is, exposure to the fluid flow will not cause detriment to the actuation system 200.

[0041] FIG. 3 is a planar cross-sectional view of an example buff body actuation system 300 that can be used with the example vortex flow meter 102. The example buff body actuation system 300 is substantially similar to the buff body actuation system 200 previously described with the exception of any differences described herein. As illustrated in FIG. 3, the actuation system 300 includes a series of shafts 302 and cables 304 to linearly oscillate the buff body 110 and supports 114

relative to the housing 106. A motor 306 turns a first shaft 302a that is coupled by a first cable 304a to a second shaft 302b. The first shaft 302a and the second shaft 302b can have a drive ratio of 1:1 or another drive ratio depending upon the speed, torque, and type of motor used. In the illustrated example, the motor 306 is bi-directional, meaning that it rotates in both directions to oscillate the buff body 110. The second shaft 302b and the third shaft 302c are coupled to one another by a second cable 304b and a third cable 304c. The drive ratio between the second shaft 302b and the third shaft 302c is irrelevant so long as the drive ratio is consistent at both ends of the second shaft 302b and third shaft 302c. Both the second cable 304b and the third cable 304c include a first carrier 306a and a second carrier 306b respectively. Each carrier (306a, 306b) can have a gondola-like structure where a portion of the carrier (306a, 306b) is attached to the cable (304a, 304b) such that the carrier (306a, 306b) does not move relative to the cable (304a, 304b). Another portion of the carrier (306a, 306b) is attached to a support 114 such that the support 114 does not linearly move relative to the carrier (306a, 306b). With such an arrangement, a carrier (306a, 306b), support 114, and the buff body 110 all move relative to the housing 106 as a cable (304a, 304b) moves. Each carrier is connected to the buff body 110 via vertical supports 114. Each support passes through the conduit via a seal 308. The seals 308 fluidically isolate the cables 304, shafts 302, and actuator 204 from the fluid flow. In some implementations, the actuation system 300 can be configured to operate in a wetted state. That is, exposure to the fluid flow will not cause detriment to the actuation system 300. While primarily described as using cables, other drive components can be used, for example belts, chains, gears, or a combination, without departing from this disclosure.

[0042] FIG. 4 is a planar cross-sectional view of an example buff body actuation system 400 that can be used with the example vortex flow meter 102. The example buff body actuation system 400 is substantially similar to the buff body actuation system 200 previously described with the exception of any differences described herein. In the illustrated implementation, the actuator 204 includes a piezoelectric material 402. The piezoelectric material 402 expands and contracts responsive to an electric signal. The expansion and contraction allows the buff body 110 and the support 114 to move relative to the housing 106. Such a signal can be provided by the controller 116.

[0043] FIG. 5 is a block diagram of an example controller 116 that can be used within the context of this disclosure. The controller 116 can, among other things, monitor parameters of the system and send signals to actuate and/or adjust various operating parameters of the system. As shown in FIG. 5, the controller 116, in certain instances, includes a processor 550 (e.g., implemented as one processor or multiple processors) and a memory 552 (e.g., implemented as one memory or multiple memories) containing instructions that cause the processors 550 to perform operations described herein. The processors 550 are coupled to an input/output (I/O) interface 554 for sending and receiving communications with components in the system, including, for example, the sensor 112. In certain instances, the controller 116 can additionally communicate status with and send actuation and/or control signals to one or more of the various system components (including an actuator system, such as actuator systems 200, 300, or 400) of the system 100, as well as other sensors (e.g., pressure sensors, temperature sensors, vibration sensors, and other types of sensors) provided in the system 100. In certain instances, the controller 116 can communicate status and send actuation and control signals to one or more of the components within the system 100, such as the actuator 204. The communications can be hard-wired, wireless or a combination of wired and wireless. In some implementations, controllers similar to the controller 116 can be located elsewhere, such as in a data van, elsewhere on a site or even remote from the site. In some implementations, the controller 116 can be a distributed controller with different portions located about a site or off site. For example, in certain instances, the controller 116 can be located at the vortex flow meter 102, or it can be located in a separate control room or data van. Additional controllers can be used throughout the site as stand-alone controllers or networked controllers without departing from this disclosure.

[0044] The controller 116 can operate in monitoring, commanding, and using the vortex flow meter 102 for measuring vortex shedding and improving a signal-to-noise ratio of a measurement signal. To monitor and vortex flow meter 102, the controller 116 is used in conjunction with the sensor 112. Input and output signals, including the data from the sensor, controlled and monitored by the controller 116, can be logged continuously by the well stack controller 50.

[0045] The controller 116 can have varying levels of autonomy for controlling the vortex flow meter 102. For example, the controller 116 can begin sensing vortex

shedding, an operator adjusts the frequency and amplitude of buff body oscillations. Alternatively, the controller 116 can begin sensing vortex shedding, receive an additional input from an operator, and begin adjusting the frequency and amplitude of the buff body oscillations with no other input from an operator. Alternatively, the controller 116 can begin sensing vortex shedding and adjust the frequency and amplitude of buff body oscillations with no input from an operator.

[0046] FIG. 6 is a flowchart of an example method 600 that can be used in the context of this disclosure. At least some of the steps described below can be performed by the controller 116. At 602, the fluid flow is received by a conduit 104. For example, hydrocarbons can be received by a flowline, or brine can be received for fluid injection. The concepts described herein can be used with other fluids and other applications without departing from this disclosure. At 604, the fluid flow is flowed over the buff body 110 within the conduit.

[0047] At 606, the buff body 110, positioned within the conduit 104 and the fluid flow, is oscillated. Oscillating the buff body significantly improves the signal-to-noise ratio of the vortex meter by differentiating the vortex shedding from the background noise of the fluid flow. For example, in some implementations, the buff body is configured to oscillate with an amplitude of up to 10 millimeters. For example, in some implementation, the buff body 110 is configured to oscillate between 0.03 hertz and 0.045 hertz. Other oscillation amplitudes and frequencies can be used depending upon the flow conditions within the conduit 104. In such instances, the controller 116 can determine an oscillation rate, oscillation amplitude, or both, that improves the signal-to-noise ratio to a pre-set level. Based on the signal response recorded from the sensor 112, the oscillations can be adjusted if desired. In some implementations, when the field conditions are well known, such a calibration step can be done in a laboratory or factory setting before the vortex flow meter 102 is installed into the conduit 104. In instances where the field conditions are unknown, an analysis of the vortex stream can be analyzed and an optimal setting can be determined in-situ. Such a determination is based upon the fluid operating conditions, such as flow-rate of the fluid, density of the fluid, and the current signal-to-noise ratio. In some implementations, the buff body can remain stationary while an initial vortex shedding measurement is taken. In such an implementation, the controller 116 can begin oscillations if the signal-to-noise ratio of the measurement is below a specified

threshold. Such a threshold is determined from the measurement accuracy. For example, if several readings are taken in sequence and all are different, then the system is not tuned and the noise is potentially greater than the proper signal. Based on the signal response, the oscillation frequencies could be changed to attain the optimal setting by changing the oscillation frequency first. Once a good signal to noise ratio is obtained based on the in-situ calibration, the oscillations amplitude could also be optimized by increasing slightly their value

[0048] The buff body can be moved in a variety of ways, for example, in some implementations, a linkage, connected to the buff body at a first end, is rotated by a motor attached to a second end of the linkage. In some implementations, one or more cables linearly translates the buff body. In some implementations, the buff body is linearly oscillated by directing a current into a piezoelectric material coupled to the buff body 110. Regardless of the implementation, the controller sends a drive signal to the actuator 204 or oscillator to oscillate the buff body 110 relative to the housing 106.

[0049] At 608, vortex shedding is produced by the buff body responsive to flowing the fluid flow over the buff body. In an event that the buff body is unable to oscillate, for example, in the case of an actuator failure, the buff body will still continue to create detectible vortex shedding, though with increased levels of noise compared to an oscillating buff body.

[0050] At 610, the vortex shedding is sensed by a sensor downstream of the buff body within the conduit. At 612, a vortex stream is produced by the sensor 112 responsive to sensing the vortex shedding. The vortex stream is indicative of vortexes shed by the buff body within the fluid and can be made up of a digital or analog signal. At 614, the vortex stream is received by the controller 116. At 616, a flow velocity is determined by the controller 116 responsive to the received vortex stream.

[0051] While this disclosure contains many specific implementation details, these should not be construed as limitations on the scope of what may be claimed, but rather as descriptions of features specific to particular implementations. Certain features that are described in this disclosure in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features may be described above as acting in

certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination.

5 [0052] For example, multiple vortex flow meters can be used to measure flow properties of the fluid flowing through the same conduit. Such vortex flow meters can be arranged in series downstream from one another with sufficient distance between to mitigate interference, for example the vortex flow meters can be spaced, for example, twelve to twenty conduit diameters in length from one another. The distance is
10 dependent upon how high the Reynolds number of the fluid flow is. The Reynolds number describes the ratio between the inertia forces to the viscous forces in the flow. The higher the Reynolds number, the greater the distance between vortex flow meters should be. In some implementations, each vortex flow meter can be different, for example, a first vortex flow meter can use concepts described in FIG. 2, a second
15 vortex flow meter can use concepts described in FIG. 3, and a third vortex flow meter can use concepts described in FIG. 4. In this manner, two or more combinations of the vortex flow meters described within this disclosure can be implemented together in a single conduit. Such implementations can be useful across pipelines, or in systems where redundancy is considered a key design factor.

20 [0053] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. Moreover, the separation of various system components in the implementations described above should not be understood as
25 requiring such separation in all implementations, and it should be understood that the described program components and systems can generally be integrated together in a single product or packaged into multiple products.

[0054] Thus, particular implementations of the subject matter have been described. Other implementations are within the scope of the following claims. In
30 some cases, the actions recited in the claims can be performed in a different order and still achieve desirable results. In addition, the processes depicted in the accompanying figures do not necessarily require the particular order shown, or sequential order, to achieve desirable results.

CLAIMS

1. A vortex flow meter comprising:
 - a housing defining a flow passage;
 - an actuatable buff body within the flow passage; and
 - 5 a sensor downstream of the actuatable buff body and attached to the housing, the sensor configured to detect vortex shedding in a fluid flowing past the buff body.
2. The vortex flow meter of claim 1, further comprising:
 - 10 a linkage attached to the buff body at a first end of the linkage; and
 - an actuator attached to a second end of the linkage, the actuator configured to oscillate the actuatable buff body.
3. The vortex flow meter of claim 2, wherein the linkage comprises a cable.
4. The vortex flow meter of claim 2, wherein the actuator comprises an electric motor or a piezoelectric material.
5. The vortex flow meter of claim 1, wherein the sensor comprises an acoustic sensor.
6. The vortex flow meter of claim 1, wherein the buff body is configured to oscillate with an amplitude of up to 10 millimeters.
7. The vortex flow meter of claim 1, wherein the buff body is configured to oscillate between 0.03 hertz and 0.045 hertz.
8. The vortex flow meter of claim 1, further comprising a controller configured to:
 - 30 send a drive signal to an oscillator to oscillate the buff body;
 - receive a vortex stream from the sensor, the vortex stream indicative of vortices shed by the buff body within a fluid; and
 - determine a flow velocity responsive to the received vortex stream.
9. The vortex flow meter of claim 8, wherein the vortex stream comprises an

analog signal.

10. The vortex flow meter of claim 8, wherein the controller is further configured to:

- 5 adjust an amplitude of oscillations in response to adjusting operation conditions; and
 adjust a frequency in response to adjusting operation conditions.

11. The vortex flow meter of claim 1, wherein the buff body is cylindrical and
10 perpendicular to the flow passage.

12. A method comprising:

- receiving a fluid flow by a conduit;
 flowing the fluid flow over a buff body within the conduit;
15 oscillating the buff body, positioned within the conduit, within the fluid flow;
 producing vortex shedding by the buff body responsive to flowing the fluid flow over the buff body;
 sensing the vortex shedding by a sensor downstream of the buff body
20 within the conduit;
 producing a vortex stream by the sensor responsive to sensing the vortex shedding by the sensor, the vortex stream indicative of vortices shed by the buff body within the fluid;
 receiving the vortex stream by a controller; and
25 determining a flow velocity by the controller responsive to the received vortex stream.

13. The method of claim 12, wherein oscillating the buff body comprises
30 oscillating the buff body with an amplitude of up to 10 mm.

14. The method of claim 12, wherein oscillating the buff body comprises to
 oscillating the buff body between 0.03 hertz and 0.045 hertz.

15. The method of claim 12, wherein oscillating the buff body comprises:
35 adjusting an amplitude of oscillations in response to adjusting operation

conditions of the fluid flow; and

adjusting a frequency in response to adjusting operation conditions.

16. The method of claim 12, wherein oscillating the buff body comprises:

5 rotating linkage, connected at a first end of the linkage to the buff body,
by motor attached to a second end of the linkage.

17. The method of claim 12, wherein oscillating the buff body comprises:

linearly translating the buff body by cable.

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18. The method of claim 12, wherein oscillating the buff body comprises:

directing a current into a piezoelectric material coupled to the buff
body.

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19. A system comprising:

a flow conduit;

a vortex flow meter within the flow conduit, the vortex flow meter
comprising:

a housing defining a flow passage substantially in-line with the

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flow conduit;

an actuable buff body within the flow passage;

a sensor downstream of the actuable buff body and attached to
the housing, the sensor configured to detect vortex shedding; and

a controller configured to:

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send a drive signal to an oscillator to oscillate the buff
body;

receive a vortex stream from the sensor, the vortex stream
indicative of vortices shed by the buff body within a fluid; and

determine a flow velocity responsive to the received vortex

30

stream.

20. The system of claim 19, wherein the vortex flow meter is at least twelve
conduit diameters in length from any bends in the conduit.

35

21. The system of claim 19, wherein the controller is further configured to:

adjust an amplitude of oscillations in response to adjusting operation conditions of the fluid flow; and
adjust a frequency in response to adjusting operation conditions of the fluid flow.

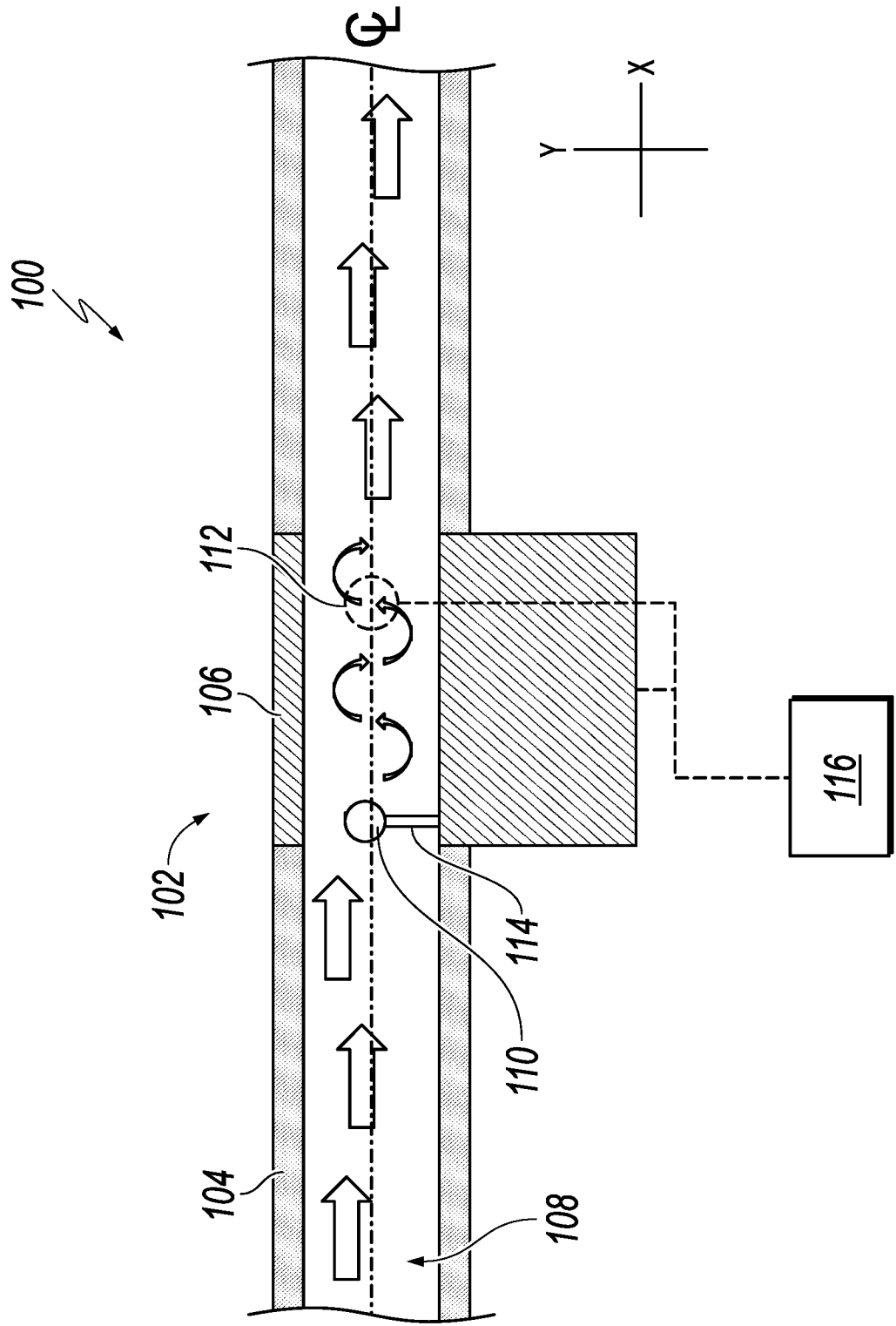


FIG. 1

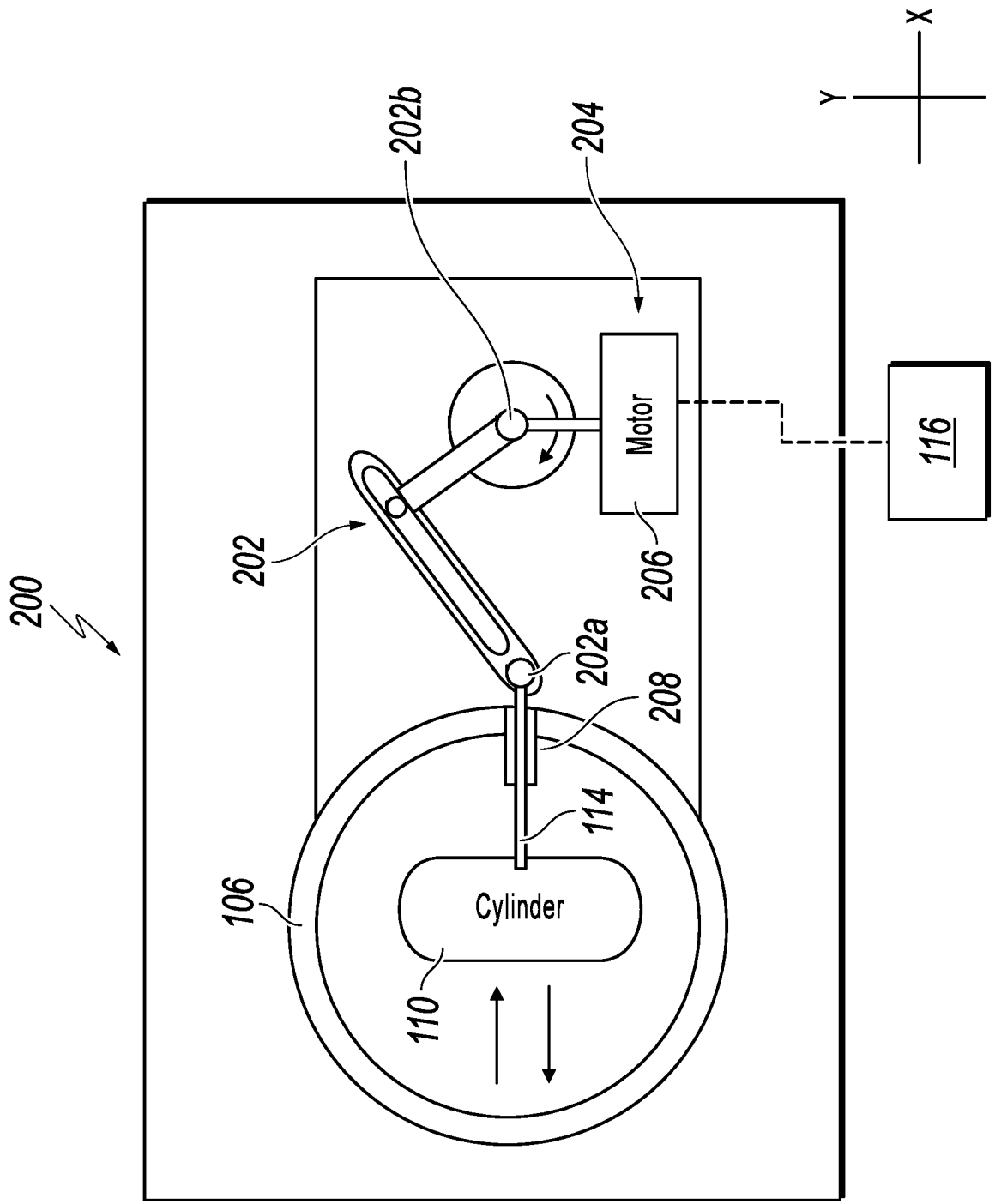


FIG. 2

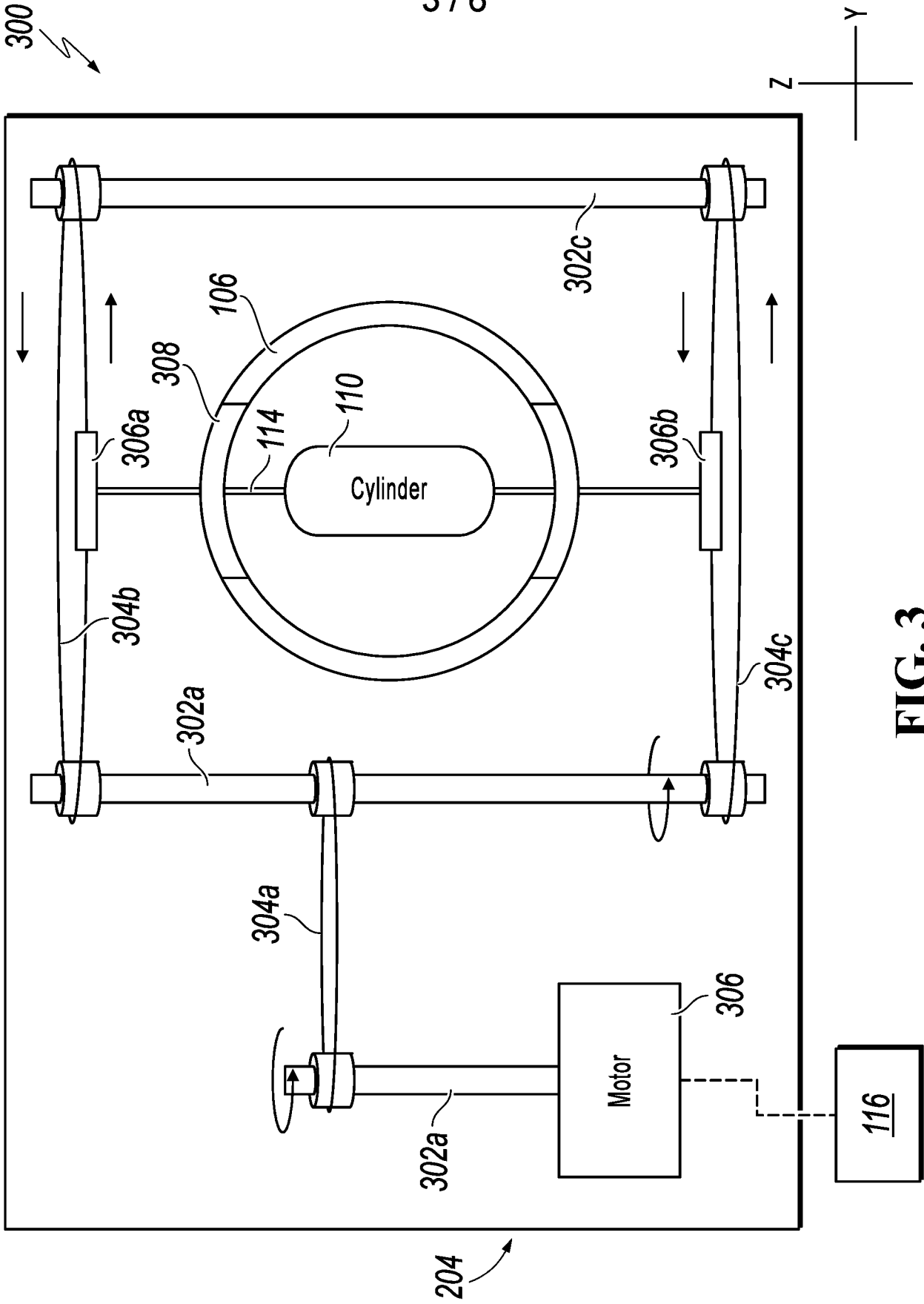


FIG. 3

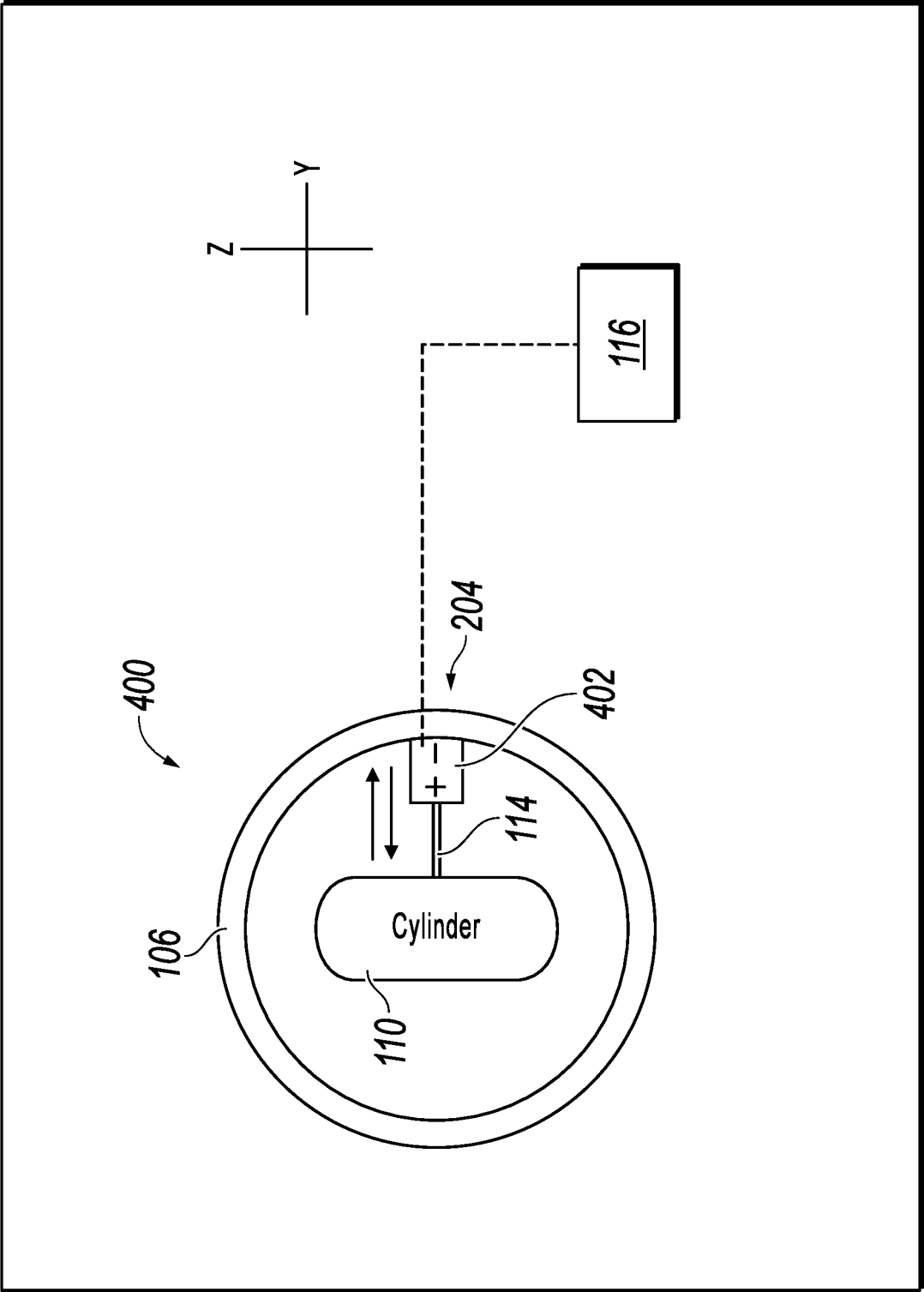


FIG. 4

5 / 6

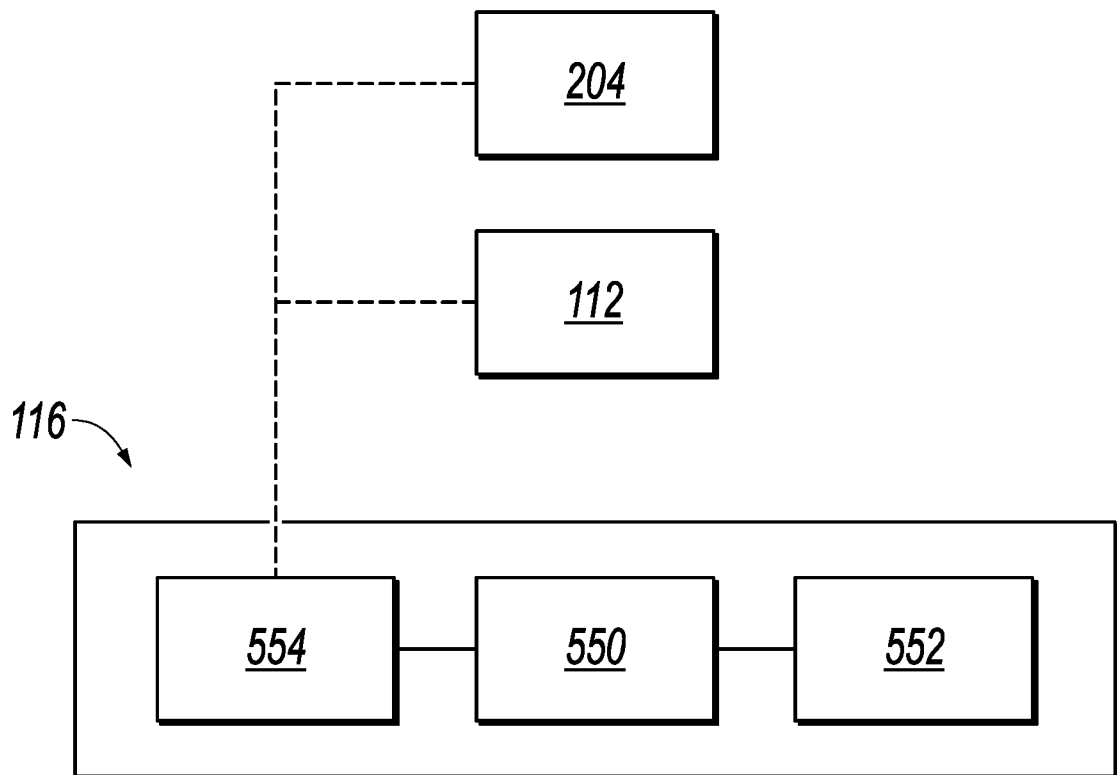
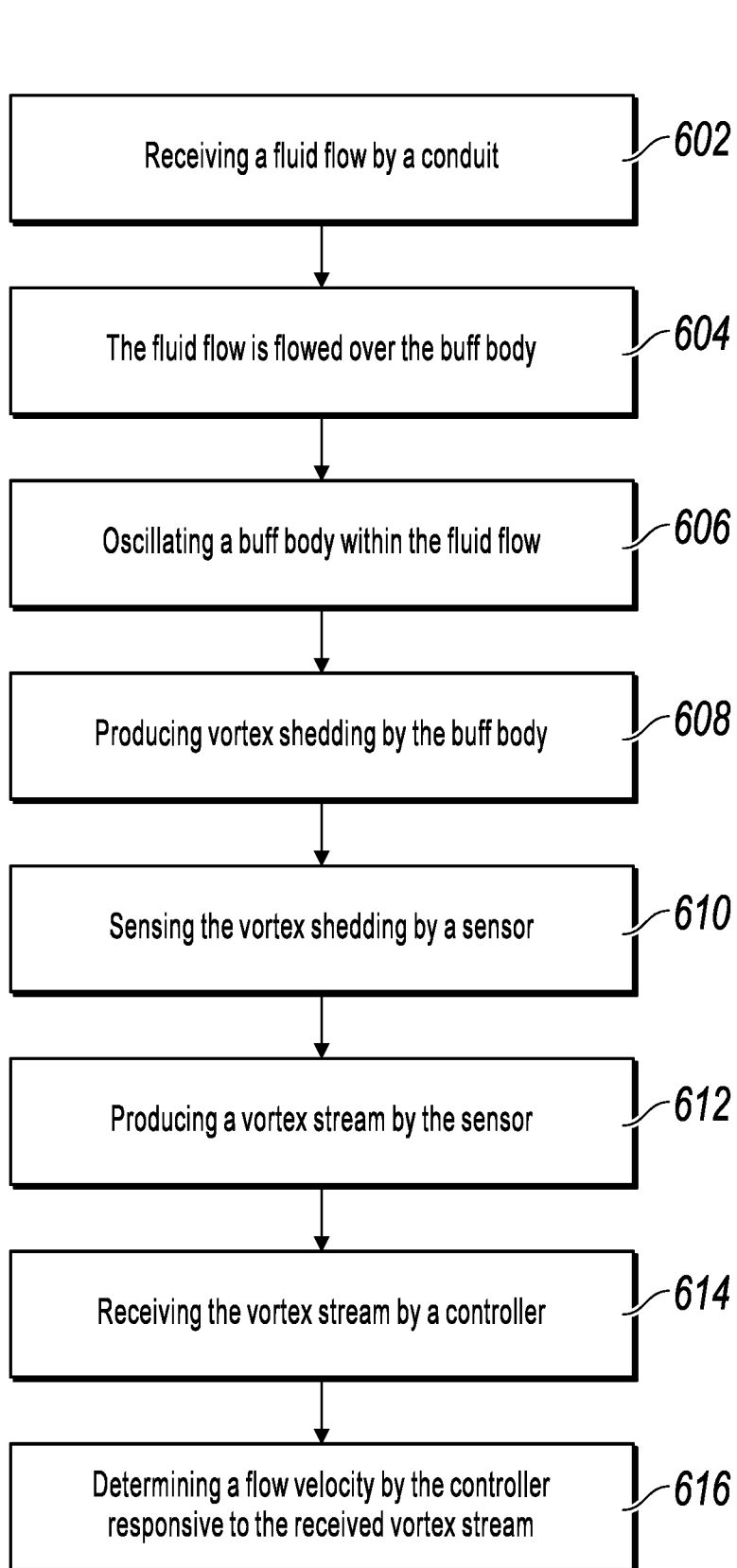


FIG. 5

6 / 6

**FIG. 6**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2021/040442

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01F1/32
ADD.

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)
G01F

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

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

EPO-Internal, WPI Data

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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

21 October 2021

Date of mailing of the international search report

02/11/2021

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Rambaud, Dilek

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2021/040442

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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