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(71) Applicant: **PIPELIFE NEDERLAND B.V.** [NL/NL]; Flevolaan 7, 1601 MA Enkhuizen (NL).

(72) Inventors: **DROOGENDIJK, Rens Ruben Ismael**; Tuinbouwweg 28, 2742 KP Waddinxveen (NL). **BOON, Bas**; Billebrinkhöhe 65, 45136 Essen (DE).

(74) Agent: **NEDERLANDSCH OCTROOIBUREAU**; P.O.Box 29720, 2502 LS The Hague (NL).

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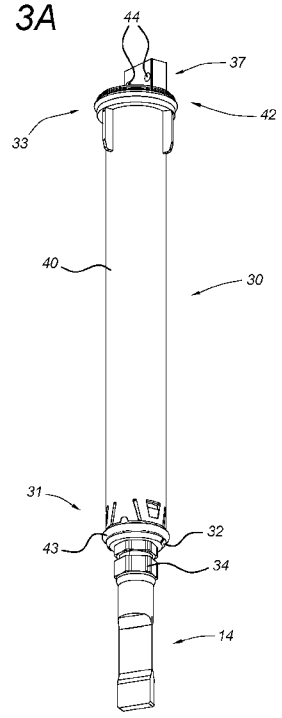
(54) **Title:** CARTRIDGE

Fig. 3A



(57) **Abstract:** A cartridge for a sensor assembly comprises a tubular body extending along an axis; a first end comprising a first coupling portion for coupling to at least a part of a sensor; and a second end comprising a second coupling portion for coupling to a movement device. The cartridge has an maximum outer diameter of about 44 mm ± 3 mm. The sensor assembly includes a housing to which the cartridge assembly is to be movably connected for moving axially with respect to the housing such that the cartridge can to be fully contained within the housing.

WO 2020/260403 A1

CARTRIDGE

BACKGROUND

[0001] A utility company provides water and/or gas to clients through a network of pipes as part of an overall distribution system. In order to do so, the utility company requires information about the water and/or gas flowing through the pipes. This implies a continuous supervision of the system to maintain normal operation, and at the same time, to indicate warning status or alarm conditions. The pipes have theretofore been coupled to a sensor. Due to the location of the pipes, which are commonly buried underground, the sensor is typically permanently installed in spaces which can be accessed, such as basements or pump stations. .

SUMMARY

[0002] According to a first aspect, a cartridge for a sensor assembly comprises a tubular body extending along an axis; a first end comprising a first coupling portion for coupling to at least a part of a sensor; and a second end comprising a second coupling portion for coupling to a movement device; wherein the cartridge has an maximum outer diameter of about 44 mm ± 3 mm. The sensor assembly comprises a housing to which the cartridge assembly is to be movably connected for moving axially with respect to the housing such that the cartridge can to be fully contained within the housing. By having the cartridge have a maximum outer diameter of about 44 ± 3 mm, the cartridge can easily be placed into or removed from a housing leading to a pipe. Such a cartridge can secure to a sensor (and possibly also one or more sensor components), and with the cartridge configuration and dimensions, the cartridge is able to provide a way to easily and efficiently provide a sensor and place it accordingly for sensing one or more measurements related to flow through a system. This is especially useful when the flow system is underground, such as a water flow pipe. The specific cartridge configuration with a maximum outer diameter allows for the cartridge to easily fit into a housing and move within it for placement in a pipe. The specific dimensions allow for easy inserting, removing, checking and/or changing a sensor from ground level with the cartridge that can connect to a sensor assembly inside a housing and move with respect to the housing. The cartridge is able to secure and protect the sensor, and possible sensor components, while being easily positionable from a ground level and compact for easier transport and storage. The compact dimensions allow for easy access of cartridge with a sensor to access a pipe underground without requiring a large access opening.

[0003] According to an embodiment, the first coupling portion comprises a cap and/or finger connecting at least partially inside the tubular body. Optionally, the cap and/or finger secures to the tubular body with a snap-fit. Further optionally, a threaded nut can be used for securing the finger, connecting around an outside of the finger and partially around the tubular body. By using such a cap or finger, a sensor and/or sensor element can be easily and securely connected to the cartridge for the cartridge to be able to move the sensor and/or sensor element into a sensing position.

[0004] According to an embodiment, the finger has a radially extending shoulder which contacts a ledge on an interior of the cartridge to secure the finger longitudinally to the cartridge. The ledge

and/or the shoulder could be annular, or interrupted. To secure the finger, it could be place into the tubular body from the second end, with the ledge being positioned near the first end. The finger shoulder connects to the ledge, stopping any further movement in the longitudinal direction. Typically, this would be at a position where the finger is extending at least partially beyond the tubular body first end. Optionally, a nut could secure around the outside of the finger, e.g., with a threaded connection between the nut and finger.

[0005] According to an embodiment, the cartridge further comprises one or more sealing elements between the cap and/or finger and the tubular body. A sealing element could also be used between the nut and cartridge. By providing sealing elements, sensitive sensor components, such as electronics, can be stored inside the cartridge thereby providing for sensing, converting, and/or storing data directly at the cartridge and sensor location.

[0006] According to an embodiment, the second coupling portion comprises a protrusion for coupling to a beam. Such a protrusion can enable an easy way to couple the cartridge to a beam, rod or other device for moving the cartridge. Optionally, the protrusion comprises a channel forming a passageway to the interior of the cartridge. Such a channel can be used to provide a path for a wired connection between sensor components inside of the cartridge and systems outside the cartridge. The channel through the protrusion and/or the beam can provide a secure and protected path for the wired connection. Further optionally, the wired path could be outside the protrusion and through a different cartridge surface. Further optionally, the second coupling portion is located in a removable cap, which secures to the second end of the tubular body. This can secure at least partially inside to ensure a sealed connection.

[0007] According to an embodiment, the axial length of the cartridge is about 266.7 mm ± 20 mm. According to an embodiment, the tubular body has an outer diameter of about 34 mm ± 3 mm. Such dimensions can ensure that the cartridge fits securely into an assembly, and particularly a sensor housing, and can position the sensor correctly for a sensing operation.

[0008] According to an embodiment, the maximum outer diameter of the cartridge is located at a rim on the cartridge. This can help to ensure that the cartridge does not come out of the housing in which it is located when fully extended. This rim can also ensure more smooth movements with respect to the housing when the cartridge is moved up and down within the housing. Optionally, a seal is associated with the rim. Such a seal can help to ensure no liquid enters into housing and can also help to ensure smooth movements between the cartridge and housing.

[0009] According to an embodiment, the tubular body is formed of plastic. The plastic could be Polyvinyl chloride ("PVC") or another type of plastic. Further optionally, the cartridge could be formed of stainless steel or another material which can be formed in the required dimensions and tolerances and is also able to withstand the conditions related to sensing in a flow (e.g., resist degradation due to liquid flow).

[0010] According to a second aspect of the invention, a housing and cartridge package comprises a housing comprising a tubular body; and a cartridge with sensor movably connected to the housing such that the cartridge can move axially with respect to the housing and fit within the housing. Such an assembly of the housing and cartridge allows for a compact package for securing, inserting and

properly placing a sensor within a sensing assembly. The cartridge and sensor can be fully contained within the housing, making a compact package which ensures sensor and components are protected for transporting to a location of a sensing assembly. The package can be pre-assembled, for example, at a different location and then transported to the site of the sending assembly. The compact package can then be easily inserted into a sensing assembly, and the cartridge with sensor can be extended from the housing for sensing operations. Having a compact package allows the sensor housing to protect the cartridge and sensor elements during transport and insertion, and the ability to extend and retract makes for easy and accurate sensor placement. Additionally, the compact package with the specific dimensions allows for the use of a number of different sensors in the system, allowing for the removal of one sensor housing and cartridge package and quick and easy insertion of another of the same dimensions.

[0011] According to an embodiment, the housing further comprises a cap and one or more rods connectable to the cartridge for moving the cartridge with respect to the housing. The cap acts as the top of the sensor housing, allowing one or more rods to connect to the cartridge for moving downward to a sensing position or upward to a compact position within the sensor housing. The cap can be easily and quickly secured to the sensor housing, for example, through a bayonet connection. The one or more rods or beams can connect to parts of the cartridge, or some may not and may simply act as pushing rods. The one or more rods or beams may also be a shape that is not cylindrical and be used to ensure that the sensor is properly oriented for insertion and proper sensing.

[0012] According to an embodiment, the housing and cartridge must be able to extend a length of at least 500 mm when the cartridge is fully extended with respect to the housing. This can ensure that a sensor element can be properly placed within a flow through a flow system.

[0013] According to an embodiment, the housing has an outer diameter of about 51 mm. The dimensions of the housing ensure that it can be easily placed into a sensing assembly, and can replace a former package being used. This can allow for conveniently and easily providing various sensors or other devices when needed, as well as easily removing the sensors or devices (e.g., for maintenance, replacement) using a compact package of a housing with the specified dimension.

[0014] According to a further aspect of the invention, there is a method of forming a cartridge for use with a sensing assembly comprises a housing to which the cartridge assembly is to be movably connected for moving axially with respect to the housing such that the cartridge can to be fully contained within the housing. The method comprises forming a tubular body extending along an axis with a first end comprising a first coupling portion for coupling to at least a part of a sensor; and a second end comprising a second coupling portion for coupling to a movement device; wherein the cartridge has an maximum outer diameter of about 44 mm ± 3 mm. Optionally, the first end and/or the second end are formed separately, and the method further comprises securing the first end and/or the second end to the tubular body. The body can be formed through molding, injection molding, machining or other techniques depending on the material used. Such a method forms a cartridge which can be used as part of a sensing assembly and can be easily placed and removed by fitting securely but movably into a housing for placement of the sensor in a flow system.

[0015] According to a further aspect of the invention, a method of forming a package of a sensor housing and a cartridge comprises forming a cartridge with sensor; and inserting the cartridge into a sensor housing such that the cartridge can move with respect to the sensor housing to extend out of the sensor housing, and such that the cartridge fits fully within the housing. Such a method forms a package which can be pre-assembled and then transported for insertion and use in a sensing assembly. It can easily be inserted and removed when needed or desired, for example, for inspection or replacement with a package with another type of sensor or a newer sensor.

[0016] According to an embodiment, the method further comprises connecting one or more rods to the cartridge for moving the cartridge with respect to the housing. The connection of one or more rods provides for a simple and controllable way of moving the cartridge between retracted and use positions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1A illustrates a cross sectional view of a sensor assembly mounted on an underground pipe with a sensor in a lowered position;

[0018] FIG. 1B illustrates a cross-sectional view of part of the sensor assembly of FIG. 1A with the sensor in a retracted position.

[0019] FIG. 2A illustrates a perspective view of a cartridge with sensor and housing from the assembly of FIG. 1A.

[0020] FIG. 2B illustrates a side view of the cartridge with sensor and housing;

[0021] FIG. 2C illustrates a cross-sectional view of the cartridge with sensor and housing;

[0022] FIG. 3A illustrates a perspective view of a cartridge with sensor;

[0023] FIG. 3B illustrates a side view of the cartridge with sensor of FIG. 3A; and

[0024] FIG. 3C illustrates a cross-sectional view of FIG. 3B;

[0025] FIG. 4A is a cross-sectional view of a second embodiment of a cartridge and housing; and

[0026] FIG. 4B is a close-up view of an end of the cartridge of FIG. 4A.

DETAILED DESCRIPTION

[0027] FIG. 1A illustrates a cross sectional view of a sensor assembly 10 mounted on an underground pipe 12 with sensor 14 in a lowered position for sensing, and FIG. 1B illustrates a cross-sectional view of part of sensor assembly 10, with the sensor 14 in a retracted position.

[0028] The assembly 10 provides access to an interior 11 of the pipe 12 such that a sensor 14 can sense at least one property of liquid or gas within the pipe 12 when in a lowered position (Fig. 1A). The assembly 10 comprises a saddle mountable on an outer circumferential surface of the pipe 12. The saddle is connected to a sensor valve 16 and a flushing valve 18. One or more of the valves 16, 18 comprise a T-tube. In one embodiment, the flushing valve 18 is connected to a T-tube. A housing 20 (which includes a tube and fitting) is also connected to the valves 16, 18 extending longitudinally away from the valves 16, 18. The housing 20 is connected to the valves 16, 18 by any suitable means. For example, the housing 20 can be connected to the valves 16, 18 by a quick connection (e.g., by a snap-on, twist-on or slide-on connection), mechanical connection (e.g., by

fasteners, such as a brackets or screws), welding, etc. In some embodiments, the housing 20 and the valves 16, 18 can be formed integrally.

[0029] When the sensor valve 16 is open, the interior 22 of the housing 20 is open to the interior 11 of the pipe 12 such that the sensor 14 is movable between a retracted position within the interior 22 of the housing 20 (FIG. 1B) and a sensing position within the interior 11 of the pipe 12 (FIG. 1A). In the sensing position, the sensor valve 16 is open and the sensor 14 is at least partially within the interior 11 of the pipe 12 to sense a property of liquid or gas within the pipe 12. In the sensing position, liquid or gas within the pipe 12 is prevented from flowing out of the pipe 12 to the interior 22 of the housing 20. In the sensing position, the sensor 14 (and sensor electronic components 15, but referred to generally as “sensor 14”) senses a property of liquid or gas within the interior 11 of the pipe 12 and relays the data to the communication device 50, which may receive, process, store and/or further relay the data. The sensor 14 can sense any property of liquid or gas including, but not limited to, temperature, pressure, flow direction and/or rate, density, conductivity, pH, viscosity, turbidity, Chlorine and other chemical compositions. In some embodiments, the sensor 14 can also sense any property related to the pipe 12, including, but not limited to, stress or strain. In some embodiments, the sensor 14 is not moved into the interior 11 of the pipe 12 and the opening simply allows for flow from the pipe 12 to where the sensor 14 or other device is located near the opening. When the sensor valve 16 is closed, the sensor 14 is prevented from accessing the interior 11 of the pipe 12.

[0030] Assembly 10 also includes sensor housing 24 extending longitudinally away from the valves 16, 18 and within the interior 22 of the housing 20. The sensor housing 24 is connected to the valves 16, 18 by any suitable means. For example, the sensor housing 24 can be connected to the valves 16, 18 by one or more radial pins 25 (see FIG. 2B) secure into one or more slots (e.g., a bayonet connection) thereby securing sensor housing 24 into assembly 10. Other possible connections could be a snap-on, twist-on or slide-on connection, fasteners, such as a brackets, clamps or screws, welding, etc. In some embodiments, the sensor housing 24 and the valves 16, 18 can be formed integrally. The sensor housing 24 can extend substantially the length of the housing 20 such that the sensor housing 24 is accessible at or near a ground surface, such as a road. Access to the interior of the sensor housing 24 is provided by opening a cap 26.

[0031] Cartridge 30 connects to sensor housing 24 and is axially moveable with respect to sensor housing 24 from a sensing position shown in FIG. 1A to a retracted position shown in FIG. 1B. Cartridge 30 is inserted into sensor housing 24, and connects to sensor 14 on a first end 31 (through cap 32 and fitting 34 (shown and discussed in detail in relation to Figs. 2A-3C). Cartridge 30 connects on second end 33 to sensor extension beam 36, which is movable with respect to cap 26 to move cartridge 30 and therefore sensor 14 with respect to tube 24 and pipe 12. Lowering rod 38 also extends through cap 26, and is movable with respect to cap 26.

[0032] Typically, sensor 14, cartridge 30 and sensor housing 24, (and possibly cap 26, extension beam 36 and lowering rod 38) are formed and connected together outside of assembly 10, for example, at another location. Then the compact package of the sensor housing 24 and cartridge 30 provides protection for the sensor 14 and components, and a compact package which can easily

be inserted into assembly 10 for use and/or swapped out with another sensor housing 24, cartridge 30 and sensor 14 package that was previously being used.

[0033] In order to sense at least one property of liquid or gas within the pipe 12, the sensor 14 is first positioned within the interior of the sensor housing 24 by sliding cartridge 30 with sensor 14 into sensor housing 24. Sensor housing 24 is inserted into assembly and secured with pin 25 locked into a slot positioned at the T-connector or another assembly 10 component. Pin can be supported by a spring so that the pin is locked into the slot acting as a safety lock and housing cannot be turned. To remove, pin can be lifted, pulled or slid out of the slot. Extension beam 36 is connected to cartridge 30, and cap 26 is secured to the end of sensor housing 24, for example, using a tool to place the cap 26 and lock it into place. Sensor valve 16 is opened, and sensor 14 is moved downward into the interior of the pipe 12 by moving lowering rod 38 and/or sensor extension beam 36 in an axially downward direction, sliding lowering rod 38 and extension beam 36 through openings in cap 26 into sensor housing 24. This movement of lowering rod 38 and/or sensor extension beam 36 moves cartridge 30 and sensor 14 axially with respect to sensor housing 24 until sensor 14 is located at least partially into the interior of pipe 12, as shown in Fig. 1A. This can be done manually or automatically. This is typically done using a tool, for example, rod 38 or another tool that rotates to controllably move lowering rod axially downward (or upward). Such a tool used for the movement of cartridge 30 and sensor 14 can connect to lowering rod 38, cap 26 and/or extension beam 36.

[0034] The assembly 10 further comprises a communication device 50 electrically coupled to the sensor 14 by wire means, though could be wireless means in some embodiments. In this manner, the communication device 50 can receive, process, store and/or further relay data from the sensor 14 regarding a property of liquid or gas within the pipe 12. The communication device 50 can also instruct sensor 14 on how frequently to take measurements. The communication device 50 can be mounted on a top portion of the housing 20 at or near the ground surface, such as a meter pit. The top portion of the housing 20 can also be flush with the ground surface and/or the sensor housing 24. The housing 20 itself can be adjusted telescopically or otherwise to vary the overall height of the assembly 10 based on the depth of the pipe 12 beneath the ground surface. The telescopic arrangement further prevents forces generated by heavy objects being placed on the top portion of the housing 20 at or near the ground surface from being transferred to the pipe 12.

[0035] A plurality of sensor assemblies can be installed in various locations as part of a distribution system. In this manner, the sensor 14 senses a property of liquid or gas within the pipe 12 and relays the data to the communication device 50. The data provides an indication data sensed by sensor 14, possibly indicating normal operation, warning status and/or alarm conditions. In one embodiment, the communication device 50 is a transceiver comprising a receiver and a transmitter. Such a device can receive data from the sensor 14 and relay the data to a server using a network, such as a local area network (LAN), wide area network (WAN), low-powered Wide area network (LORA, Narrowband IoT) or any other suitable network. The server can periodically or continuously receive data. The server can also request data on demand. In one embodiment, the server is associated with a data management company (e.g., a water or gas utility company) that manages

sensor data and makes the data available to its clients as desired, such as via a web site or other remote device. The communication device 50 also comprises a battery, which can easily be changed by opening the communication device 50 and swapping an empty battery with a new one. The assembly 10 allows for data to be relayed from the sensor 14 to the communication device 50 automatically or on-demand in order to monitor the conditions within (or around) the pipe 12. This allows the data to be accessible to interested parties, such as a water or gas utility company or their clients.

[0036] The sensor 14 can be any suitable type of sensor for sensing various properties of liquid or gas. In some embodiments, the sensor 14 can be a pressure sensor for measuring the water pressure at a particular location in a water distribution system, a flow rate and/or direction sensor for measuring the rate and/or direction in which water is flowing through a particular location in a water distribution system, a temperature sensor, electrical conductivity sensor, pH sensor, oxygen sensor, density sensor, viscosity sensor, turbidity sensor, Chlorine and other chemical compositions or any combination thereof, which could be connected to cartridge 30 and/or other components.

[0037] As described in the background, past systems with underground pipes that had sensors monitoring various properties typically had such sensors permanently installed. The assembly 10 allows for sensors to be conveniently and easily installed and removed from the surface. The use of a cartridge 30 to which one or more sensor components can be secured and then connected inside a sensor housing 24 forming a compact package allows for simple and quick insertion and removal of sensor 14, as well as movement between a sensing and retracted position. The use of removable sensor housing 24 and cartridge 30 which simply slides into and secures to the assembly 10 allows for pre-assembly at any location, and also enables easy replacements, as any desired type of sensor can be secured to cartridge 30, and one cartridge 30 (and possibly sensor housing 24) can be removed and easily replaced with another of the same general shape. Extension beam 36 can be disconnected from the first cartridge, and then secured to new cartridge 30 containing the new sensor.

[0038] FIG. 2A illustrates a perspective view of a cartridge 30 with sensor 14 and sensor housing 24 from assembly 10 without other surrounding assembly 10 components, FIG. 2B illustrates a side view, and FIG. 2C shows a cross-sectional view of FIG. 2B. Sensor housing 24 of FIG. 2A is also shown in a see-through state for viewing purposes.

[0039] Cartridge 30 connects to sensor 14 at first end 31, and to sensor housing 24 and extension beam 36 at second end 33. Extension beam 36 connects to protrusion 37 on cartridge 30, which extends from the substantially tubular cartridge body 40. In the embodiment shown, extension beam 36 secures to protrusion 37 through pins or bolts, which can be easily secured and removed when desired. Connection between extension beam 36 and cartridge 30 can also be through other means, for example snap connection, clamping, etc. so long as beam 36 can be secured to cartridge 30 to facilitate movement of cartridge 30 within sensor housing 24 in an upward or downward direction.

[0040] Second end 33 of cartridge 30 also includes rim 42 (which can include a sealing element such as an o-ring). Rim 42 extends slightly larger in diameter than cartridge body 30 such that only

rim 42 (and/or sealing element with rim) connects circumferentially to an inner side of sensor housing 24. Rim 42 shown in the embodiment pictured consists of an extended upper and lower portion with a recessed area to hold a sealing o-ring. The upper and/or lower portion (and other portions of cartridge in general which may come into contact with sensor housing 24) can include bevelled or rounded edges. This facilitates easier movement of cartridge with respect to sensor housing 24 as well as a sealing connection between sensor housing 24 and cartridge 30. However, other embodiments, could include different configurations for rim 42, protrusion 37 and/or second end 33.

[0041] Beam 36 is rectangular in shape in the embodiment shown and fits through a rectangular opening in cap 26. This ensures that cartridge 30 and therefore sensor 14 are oriented correctly for measurements when inserted into pipe 12 (see Fig. 1A). Some sensors 14 would not require a particular orientation, and thus, in some embodiments beam 36 could be cylindrical and not disposed or limited to a certain orientation. Beam 36 can be hollow to facilitate wired connection between sensor components 15 inside cartridge 30 and communication device 50. The interior of beam 36 connects to the interior of cartridge 30 through channel 41 in protrusion 37 (see FIG. 3C) to form the path for wired connection. In other embodiment, the path for a wired connection could be different and not through beam 36.

[0042] Lowering rod 38 can connect to the second end 33 of cartridge 30, which is typically closed with the exception of the channel 41 through protrusion 37 (see FIG. 3C). Lowering rod 38 can then be used as additional lowering force on cartridge 30 to ensure it is lowered stably and quickly with respect to sensor housing 24 and assembly 10. In some embodiments, lowering rod 38 could interact with a feature on or connected to cartridge 30, such as a recess or lug, and in other embodiments lowering rod 38 end would simply push on an end of cartridge 30.

[0043] When it is desired to change, replace, check and/or repair sensor 14, beam 36 and /or rod 38 can be pulled upward (either manually, by spinning rod, or otherwise) into a retracted position. Sensor housing 24, cartridge 30 and sensor can then be removed from assembly 10 by disconnecting the pin 25 in slot. This can be through a tool which connects to cap 26 for removing the package. Once removed, cap 26 and beam 26 can be disconnected from sensor housing 24 and cartridge 30; and can then be replaced to another sensor housing and cartridge package for insertion into assembly 10. In some embodiments, cartridge 30 with sensor 14 could be removed from sensor housing 24.

[0044] FIG. 2C shows example dimensions of sensor housing 24 length H_L of about 442 mm, extension beam 36 length EB_L of about 440 mm, lowering rod 38 length LR_L of about 434.6 mm, sensor housing inner diameter SH_{ID} of about 45.8 mm, and sensor housing outer diameter SH_{OD} of about 50.8 mm. While these dimensions are shown, they are example dimensions, and could vary depending on the size of assembly 10, extension beam 36, sensor housing 24, etc.

[0045] FIG. 3A shows a perspective view of cartridge 30 and sensor 14, FIG. 3B shows a side-view of cartridge 30 and sensor 14, and FIG. 3C shows a cross-sectional view of cartridge 30 with sensor 14. Cartridge 30 includes cartridge body 40, protrusion 37 with channel 41 and rim 42. Cartridge also includes cap 32 and/or other element facilitating a connection to sensor 14 and

forming a seal between the part of sensor 14 which is to extend into pipe 12 and the inside of cartridge 30. Cap 32 can be snap-fit into first end of cartridge body 40 or securely connected in another way. As can be seen in FIGS. 3A-3B, protrusions around the outer circumference of cap fit into recesses or holes in cartridge body 40 to secure cap 32 to cartridge body 40. O-ring seal 43 extends around cap 32.

[0046] Cartridge body 40 and second end 33 can be formed integral, for example, through molding, printing, machining or other suitable processes. Cartridge 30 can be made of plastic, for example, PVC or could be formed of stainless steel or other metals or materials in other embodiments. In some embodiments, parts, such as second end 33 and/or projection 37, of cartridge 30 could be formed separately and then secured to cartridge body 40, for example, by adhesive, welding, clamping or other connection means. Cartridge body 40 is typically tubular and hollow to house one or more sensors and/or sensor components. Ribs 45 and/or other elements can form a part of cartridge 30 to add strength and/or stability, and can be added to ensure that cartridge 30 can only move downward with respect to sensor housing 24 to a certain point (e.g., at the end of a ribs 45) and could not extend or "fall" out of sensor housing 24 when fully extended. Sensor housing 24 can also include a rim or other features to help facilitate this.

[0047] Sensor 14 connects to cap 32 with through-fitting 34, which secures to cap 32 through a threaded connection. As can be seen in FIG. 3C, sensor 14 has a tight-fit connection extending from one side to the other of through-fitting 34. Sensor electronic components 15, for example a printed circuit board ("PCB") are located inside cartridge 30. They can be secured to cartridge body 40 and/or cap 32 through adhesive, a mount, or any other suitable means. Wired connection can then extend from electronics through channel 41. Wired connection can then go through extension beam 36 (or in some embodiments could be outside extension beam 36 to communication device 50).

[0048] Protrusion 37 extends axially from second end 33 of cartridge 30 to secure to extension beam 36. Protrusion 37 is a rectangular protrusion with two holes 44 for receiving securing pins or bolts. In other embodiments, protrusion 37 and/or securing elements can take other forms for providing an easy but secure connection between extension beam 36 and cartridge 30.

[0049] Dimensions shown in FIG. 3C are cartridge length C_L of about 291.3 mm, protrustion length P_L of about 24.6 mm, cartridge body diameter B_D of about 34 mm, cartridge rim diameter R_D of about 44 mm, a length of cap extending outside cartridge body L_C of about 11.8 mm. While these dimensions are shown, they are example dimensions, and could vary depending on the size of assembly 10, extension beam 36, sensor housing 24, etc.

[0050] Sensor housing 24 and cartridge 30 together provide a secure and efficient way to easily insert and remove sensor 14 from assembly 10. Sensor 14 electronics 15 can be secured on an inside of the sensor cartridge 30 or to cap 32 (e.g., through a frame or holder), and then cap 32 can be snap fit into first end of cartridge 31. Sensor 14 can be connected into through fitting 34, and then through fitting can be secured to cap 32. Cartridge 30 can then be inserted into sensor housing 24. Cartridge 30 can be placed in a fully retracted position, such that all of cartridge 30 and sensor 14 is contained within sensor housing 24. At this point sensor housing 24 and cartridge 30 form a

compact and secure package, especially useful for storage and/or transportation, which can then be inserted into assembly 10 for sensing an element associated with flow through pipe 12. As described in relation to FIGS. 2A-2C, cap 26 with beam 36 and rod 38 can be removed from assembly, and beam 36 is secured to cartridge 30 protrusion 37, with bolts or pins used to connect through protrusion 37 and beam 36. Cap 26 can then be reconnected to the top of sensor housing 24, and extension beam 36 and/or lowering rod 38 can be used to move cartridge 30 with sensor 14 through sensor housing 24, lowering sensor 14 to a desired position with respect to pipe 12. Sensor cap 32 with o-ring form a sealed connection, preventing any liquid or gas flowing through pipe from entering the inside of cartridge 30.

[0051] When it is desired to check, repair and/or change sensor 14, the above process is simply done in reverse. Extension beam 36 is moved upward, moving cartridge 30 and sensor 14 axially upward into sensor housing 24. Once cartridge 30 second end 33 is at or near the top of sensor housing 24, the package can be removed by disconnecting sensor housing 24 from assembly 10, and removing the sensor housing 24 and cartridge 30 in the retracted position. Cap 26 is then removed and extension beam 36 can be disconnected from cartridge 30 protrusion 37. A replacement cartridge could then be connected to extension beam 36 and cap can be connected to the associated replacement sensor housing 24. The replacement package can then be inserted into and secured to assembly 10, allowing for very little downtime of assembly 10 when it is desired to check, repair or replace a sensor. The specific shape and size of sensor housing and cartridge allows for space to hold and secure sensor components and ensure they are not damaged by any liquid or other particles entering cartridge, and ensure cartridge fits securely into and moveably with respect to sensor housing 24, and the package secures to and works well with assembly 10. Additionally, channel 41 allows for a wired connection of sensor 14 and communication device 50 when desired.

[0052] Having a sensor housing 24 and cartridge 30 package with configurations which can secure and protect sensor and associated components provides a secure package which can be delivered to an assembly without worrying about damaging sensor components. The sensor housing 24 and cartridge 30 package can then be easily and efficiently exchanged with the existing sensor housing and cartridge package in the assembly. The shape and configuration of the sensor housing 24 and cartridge 30 also allows for use with a number of different sensors and allows for the securing of different sensor components in the interior of the cartridge, providing for an efficient process even when switching from one type of sensor to another in an assembly. This could, for example, facilitate easy measurement of a number of different properties of a flow by simply changing out cartridges at an assembly 10.

[0053] FIGS. 4A-4B show a further embodiment of a cartridge 30‘ with sensor and housing 24’. Similar parts are labeled similarly, with differences discussed. Cartridge 30‘ includes cartridge body 40’, which has openings on both ends. On this embodiment, cartridge body 40’ second end 33’ is open and cap 60 connects to body 40’, and to beam 36. Cap 60 can connect securely to the end of cartridge body 40’ through a click mechanism or other secure and stable coupling. As can be seen in the FIG. 4A, at least part of cap 60 connects inside body 40’, and can include an O-ring

or other seal. As can be seen, in this embodiment, protrusion 37 is on cap 60, and a further sealing element, such as cable gland 61 can be used.

[0054] First end 31' of cartridge 30' has a finger 62 and nut 64. Finger 62 extends from an inside of cartridge body 40' to an outside to be able to expose the one or more sensors, for example a conductivity sensor, when cartridge 30' is extended with respect to housing 24' (as explained in detail in relation to the embodiments above). Finger 62 can have different dimensions and configurations depending on the sensor(s), and is typically inserted into cartridge 30' from second end 33. Sensor electronics or other components can be connected to finger 62 inside cartridge 30'. Shoulder 66 catches on ledge 67 of cartridge body 40', with seal 68 ensuring that no liquid is able to enter the interior of cartridge, thereby protecting any electronics or other components inside cartridge 30'. Shoulder 66 can extend radially around the entire circumference of finger 62 or could be interrupted.

[0055] Finger 62 has exterior threads on the part which extends longitudinally just outside cartridge body 40', and nut 64 has interior threads which screw onto the exterior finger threads to secure finger 62 to cartridge 30'. Nut 64 also extend over an outside of cartridge 30', and one or more further seals 69 can also be used.

[0056] Example dimensions of cartridge body are about 273 mm in length, with an inner diameter of about 31 mm, and an outer diameter of about 35 mm. Such an outer diameter ensures that a cartridge with sensor could easily be inserted into and through a housing, enabling efficient checking and changing of cartridges and/or sensors.

[0057] Cartridge body 40', cap 60, finger 62 and/or nut 64 can all be made of plastic, for example, through injection molding. Cartridge body 40' could be formed with a closed first and/or second end, and then machined open to have the precise opening dimensions needed for the finger 62. Finger 62 (possibly with sensor(s), electronics or other components connected) can be inserted from second end 33', and finger 62 shoulder 66 is supported by the precisely machined opening. Nut 64 can be attached around the outside through threads. Such a configuration provides an efficient and simple method of forming a cartridge 30', which can easily receive and secure a variety of configurations of fingers 62 thereby allowing for use with a variety of different sensors. The precise machining, securing with shoulder 66 and nut 64, as well as one or more additional seals ensures a secure and water-tight connection for protection of all internal components. The extension into and out of housing 24' is in the same manner as described above.

[0058] While the embodiments are shown and described as the cartridge 30 and sensor 14 being a self-contained unit which can be switched out and replaced, in some embodiments, sensor 14 could simply be removed from cartridge 30, for example by disconnecting through-fitting 34 from cap 32 and removing sensor electronic components 15 or removing finger 62; and then connecting a new sensor. The ability to easily connect and disconnect cap 32 and/or finger and nut from cartridge body 40 would enable the reuse of cartridge 30, 30'.

[0059] Although the pipe 12 is described herein as an underground pipe, it should be appreciated that the pipe 12 can be completely or partially above ground. Fig. 1A shows a single assembly 10. However, a plurality of assemblies can be installed in various locations as part of a distribution

system. The assembly 10 may additionally comprise any number of suitable connectors (e.g., fasteners) to facilitate a secure connection between the component parts.

[0060] While a sensor 14 and finger 62 are described and shown, the assembly 10 can facilitate access to the pipe 12 and/or flow for other devices or tools as well, for example, tools for use with the pipe 12 or assembly 10, etc. In some embodiments, tools for use with the pipe 12 or assembly 10 may be required for maintenance, repair, testing, etc. Power generation or power management systems may be also required.

[0061] While dimensions of cartridge 30 and cartridge components are given, these are examples and could vary in different embodiments.

[0062] While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

CLAIMS

1. A cartridge for a sensor assembly comprising a housing to which the cartridge is to be movably connected for moving axially with respect to the housing such that the cartridge can be fully contained within the housing, the cartridge comprising:

a tubular body extending along an axis;

a first end comprising a first coupling portion for coupling to at least a part of a sensor; and

a second end comprising a second coupling portion for coupling to a movement device;

wherein the cartridge has an maximum outer diameter of about 44 mm ± 3 mm.

2. The cartridge of claim 1, wherein the first coupling portion comprises a cap or finger connecting at least partially inside the tubular body.

3. The cartridge of claim 2, wherein the cap secures to the tubular body with a snap-fit.

4. The cartridge of claim 2, wherein a shoulder of the finger contacts a ledge on the interior of the cartridge to secure the finger to the cartridge.

5. The cartridge of claim 4, and further comprising a nut securing around the finger.

6. The cartridge of any of claims 2-5, and further comprising one or more sealing elements between the cap or finger and the tubular body.

7. The cartridge of any of the preceding claims, wherein the second coupling portion comprises a protrusion for coupling to a beam.

8. The cartridge of claim 5, wherein the protrusion comprises a channel forming a passageway to the interior of the cartridge.

9. The cartridge of any of the preceding claims, wherein the axial length of the cartridge is about 266.7 mm ± 20 mm.

10. The cartridge of any of the preceding claims, wherein the tubular body has an outer diameter of about 34 mm ± 3 mm.

11. The cartridge of any of the preceding claims, wherein the maximum outer diameter of the cartridge is located at a rim on the cartridge.

12. The cartridge of claim 11, and further comprising a seal associated with the rim.

13. The cartridge of any of the preceding claims, wherein the tubular body is formed of a plastic material.

14. The cartridge of any of the preceding claims, wherein the second coupling portion is in a cap which connects to the tubular body at the second end.

15. A housing and cartridge assembly comprising:

a housing comprising a tubular body; and

the cartridge of any of the preceding claims movably connected to the housing such that the cartridge can move axially with respect to the housing and fit within the housing.

16. The housing and cartridge assembly of claim 15, wherein the cartridge and sensor can be fully contained within the housing.

17. The housing and cartridge assembly of any of claims 15-16, wherein the housing further comprises a cap and one or more rods connectable to the cartridge for moving the cartridge with respect to the housing.

18. The housing and cartridge assembly of any of claims 15-17, wherein the housing and cartridge must be able to extend a length of at least 700 mm when the cartridge is fully extended with respect to the housing.

19. The housing and cartridge assembly of any of claims 15-18, wherein the housing has an outer diameter of 50.8 mm ± 3 mm.

20. A method of forming a cartridge for use with a sensing assembly comprising a housing to which the cartridge is to be movably connected for moving axially with respect to the housing such that the cartridge can to be fully contained within the housing, the method comprising:

forming a tubular body extending along an axis with a first end comprising a first coupling portion for coupling to at least a part of a sensor; and a second end comprising a second coupling portion for coupling to a movement device;

wherein the cartridge has an maximum outer diameter of about 44 mm ± 3 mm.

21. The method of claim 20, wherein the first end and/or the second end are formed separately, and the method further comprises securing the first end and/or the second end to the tubular body.

22. A method of forming an assembly of a sensor housing and a cartridge, the method comprising:

forming the cartridge according to any of claims 1-14; and

inserting the cartridge into a sensor housing such that the cartridge can move with respect to the sensor housing to extend out of the sensor housing.

23. The method of claim 22, and further comprising:

connecting one or more rods to the cartridge for moving the cartridge with respect to the housing.

Fig. 1A

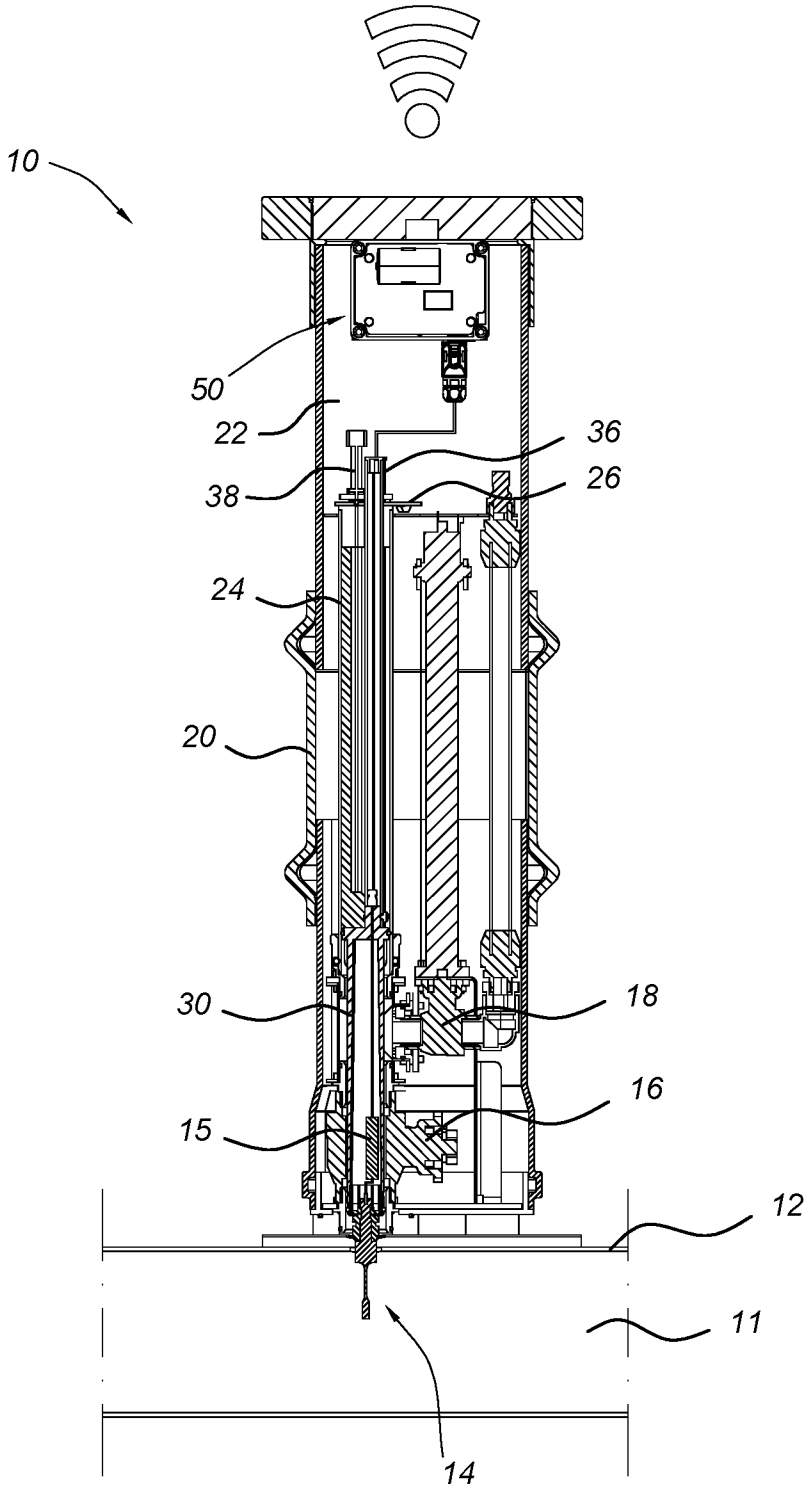


Fig. 1B

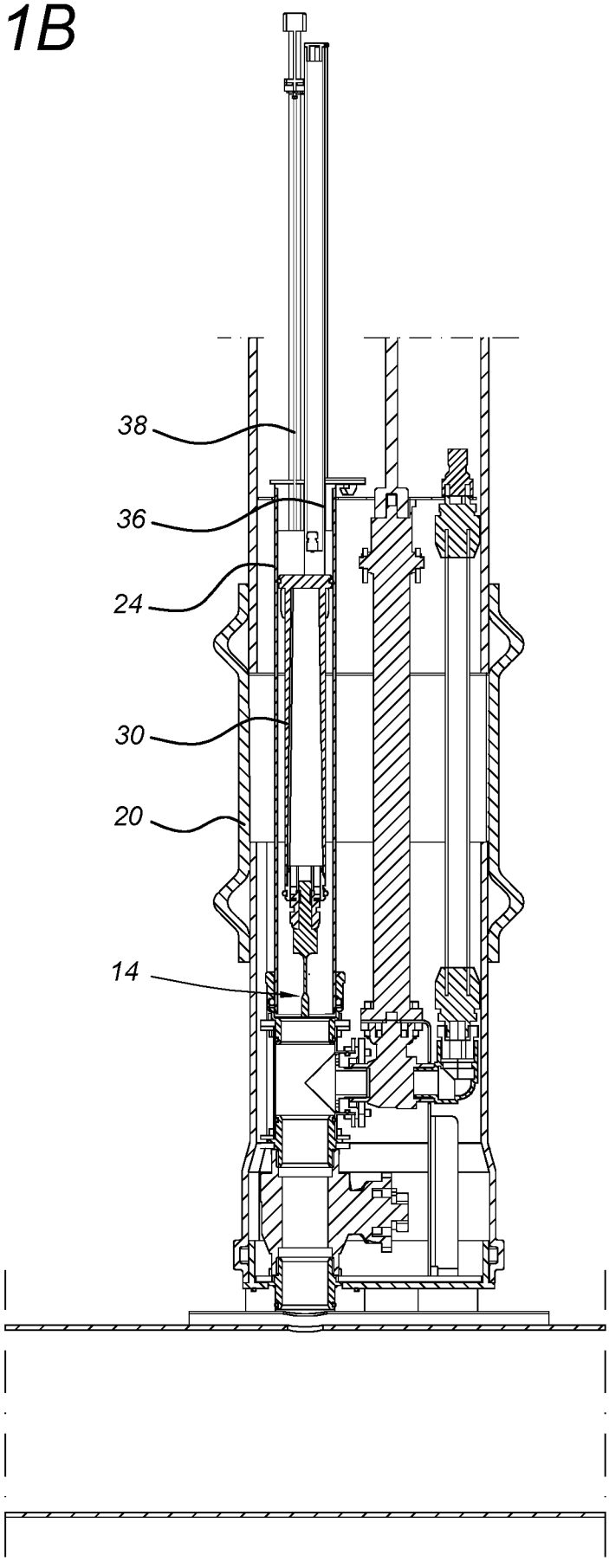


Fig. 2A

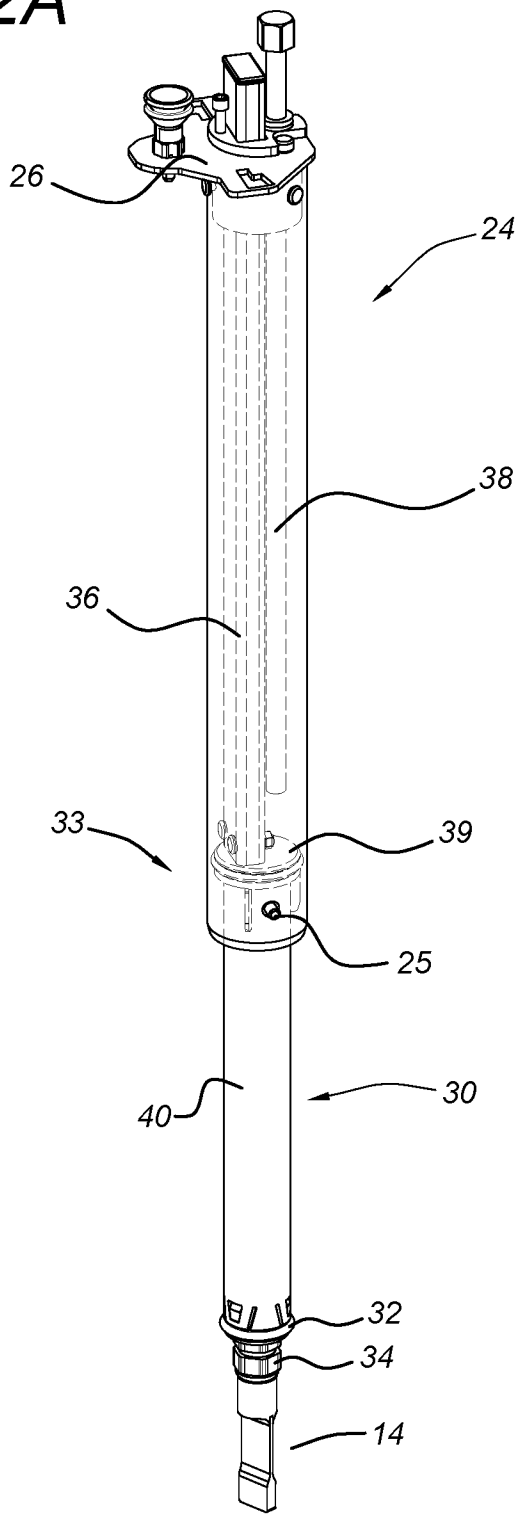


Fig. 2B

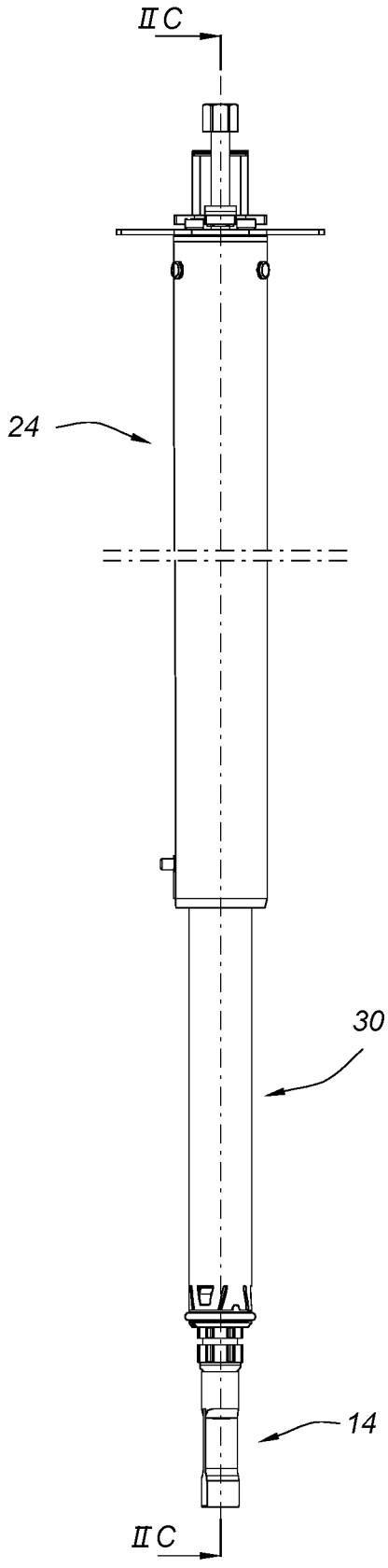


Fig. 2C

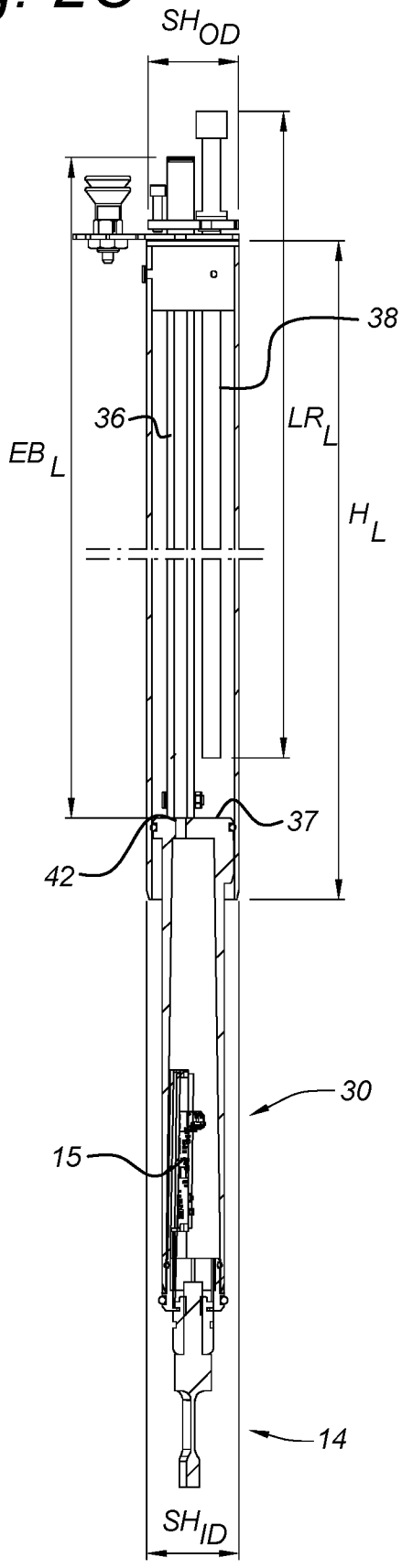
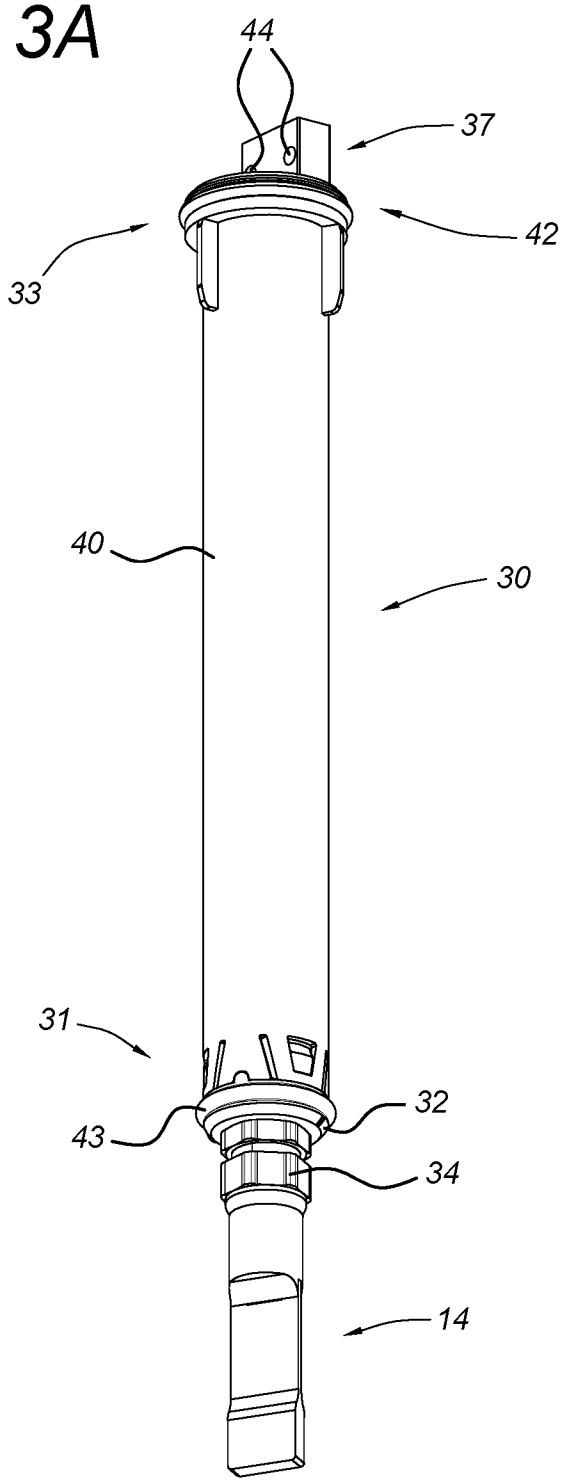


Fig. 3A



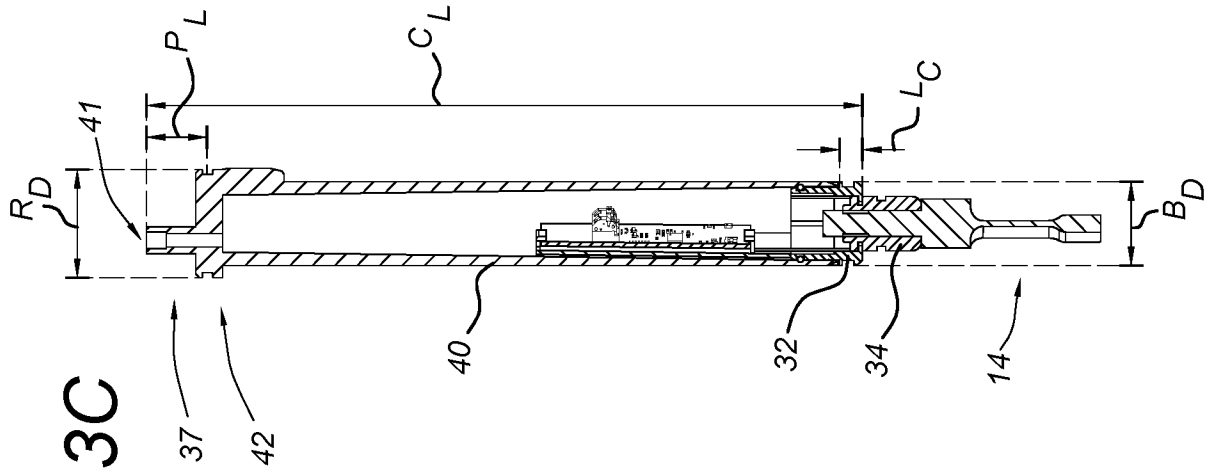

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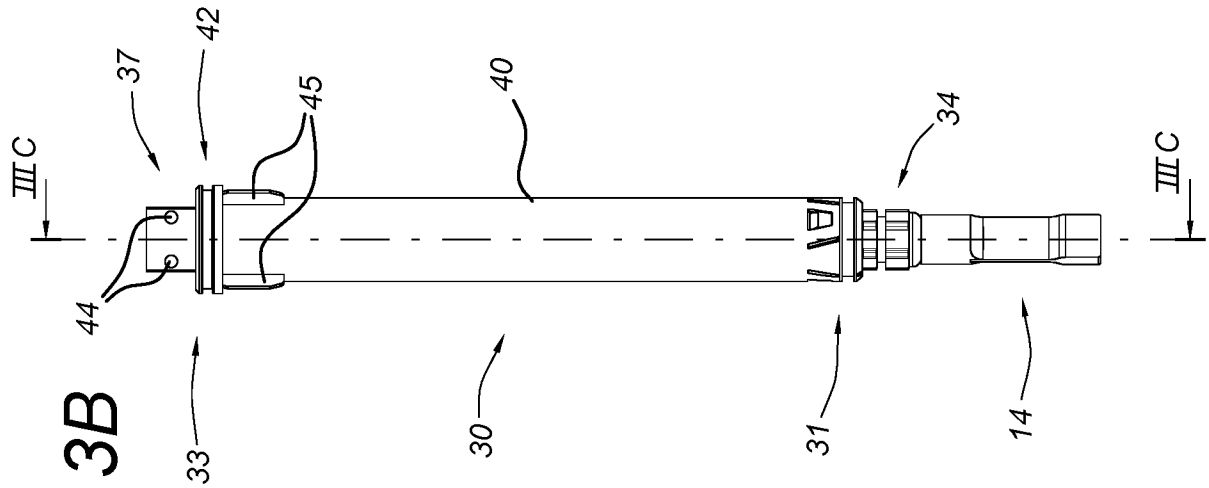
Fig. 3C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III C
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14

Fig. 3B

Fig. 4A

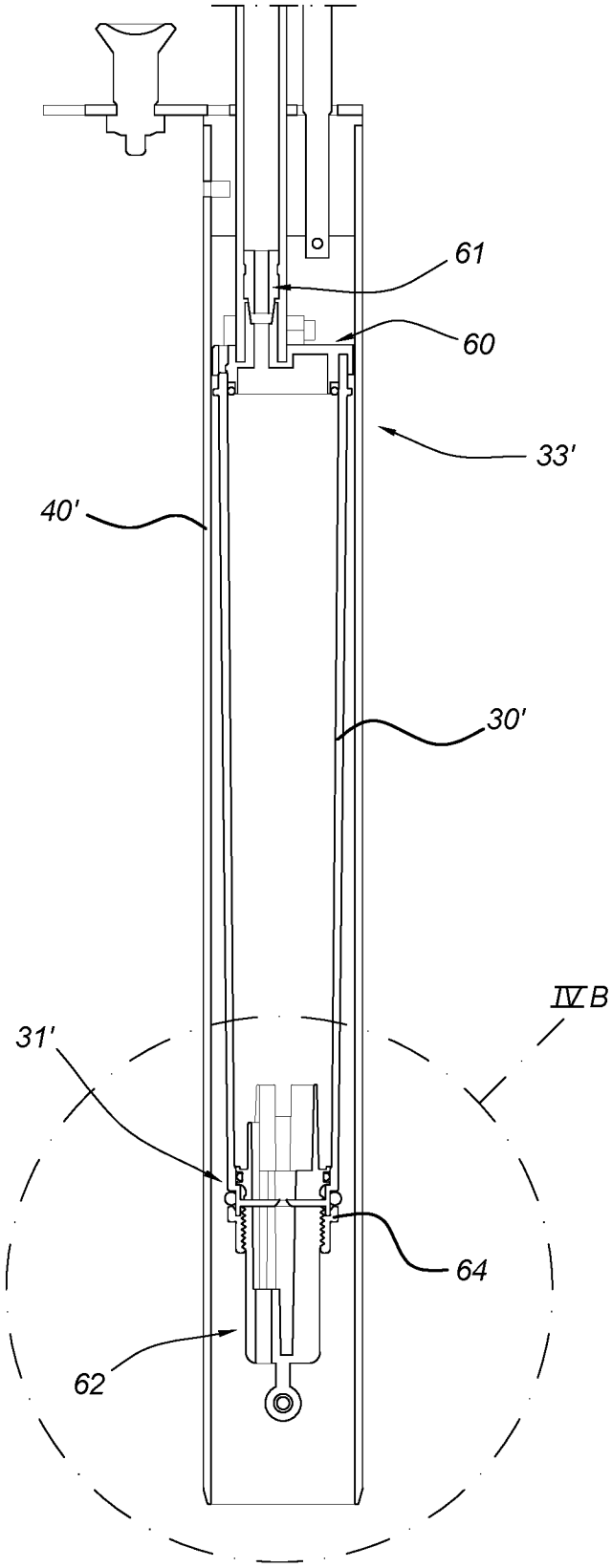
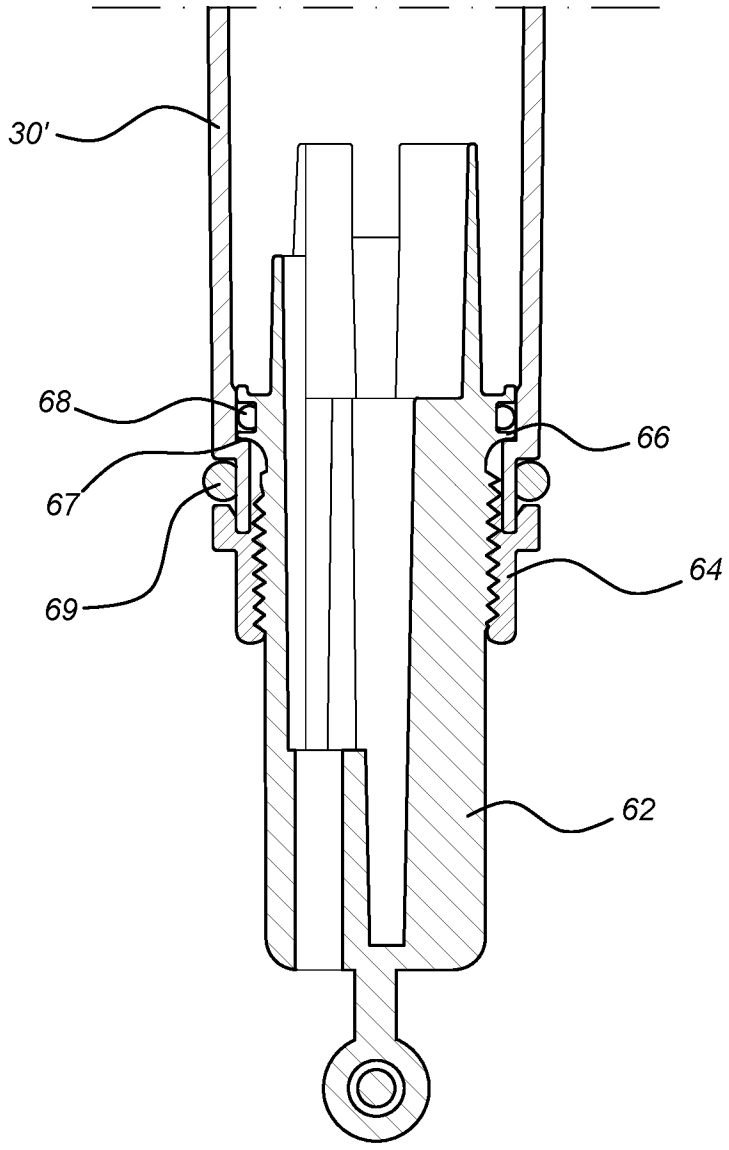


Fig. 4B



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/067728

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01D11/30 G01D21/00 G01F15/18 G01K1/14 G01K13/02 G01L19/00
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)
G01D G01W G01L G01F G01K G01N

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 20 2011 000102 U1 (POSTBERG & CO DRUCKLUFT CONTROLLING GMBH [DE]) 21 April 2011 (2011-04-21) paragraphs [0019], [0043] - [0056]; figures 3, 4, 9	1-23
A	FR 2 700 348 A1 (SAGEP [FR]) 13 July 1994 (1994-07-13) page 2, line 15 - page 4, line 5; figures 1, 2	1-23
A	EP 0 753 737 A2 (HORIBA LTD [JP]) 15 January 1997 (1997-01-15) column 3, line 1 - column 5, line 20; figures 1 - 3	1-23

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" 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

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"Y" 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

Date of the actual completion of the international search	Date of mailing of the international search report
16 September 2020	24/09/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Stobbelaar, Mark

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2020/067728

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