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(71) Applicant (for FR only): **SERVICES PETROLIERS SCHLUMBERGER**; 42, rue Saint Dominique, F-75007 Paris (FR).

(71) Applicant (for AE, AL, AM, AU, AZ, BG, BY, CL, CO, CZ, DE, DK, GR, HU, ID, IE, IL, IT, KG, KP, KZ, LT, MD, MX, MY, NO, NZ, OM, PE, PL, RO, RU, SI, SK, TJ, TM, TN, TR, TT, UA, UZ, ZA only): **SCHLUMBERGER TECHNOLOGY B.V.**; Parkstraat 83-89, NL-2514 JG The Hague (NL).

(71) Applicant (for GB, JP, NL only): **SCHLUMBERGER HOLDINGS LIMITED**; PO Box 71, Craigmuir Chambers, Road Town, Tortola (VG).

(71) Applicant (for CA only): **SCHLUMBERGER CANADA LIMITED**; 525 - 3rd Avenue S.W., Calgary, Alberta (CA).

(71) Applicant (for all designated States except AE, AL, AM, AU, AZ, BG, BY, CA, CL, CZ, DE, DK, FR, GB, GR, HU, IE, IT, KG, KZ, LT, MD, NL, NO, PE, PL, RO, RU, SI, SK, TJ, TM, TR, ZA): **PRAD RESEARCH AND DE-**

VELOPMENT LIMITED; PO Box 71, Craigmuir Chambers, Road Town, Tortola (VG).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **RAMOS, Rogerio Tadeu** [BR/GB]; 12 Collingbourne Drive, Chandlers Ford, Eastleigh Hampshire SO53 4SW (GB).

(74) Agent: **HYDEN, Martin**; Rouse Patents, 1st Floor, 228-240 Banbury Road, Oxford Oxfordshire OX2 7BY (GB).

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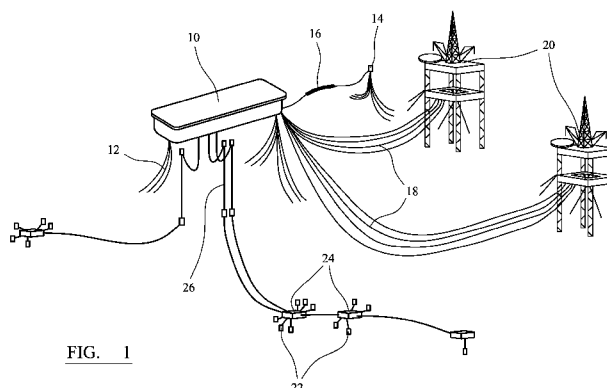


FIG. 1

(57) Abstract: Apparatus for monitoring the structural condition of a pipe is provided which comprises at least one transducer carrying apparatus locatable on the outside of the pipe, the transducer carrying apparatus including at least one transducer located thereon to detect a change in the condition of the pipe, along its length, the transducer being both a sensor and an actuator, and a signal emitted in the proximity of the transducer being detectable by the transducer, the signal representing a change in the condition of at least one component of the pipe on which the transducer is located, along its length. The invention further provides a method of monitoring the structural condition of a pipe.

Description

MONITORING OF THE STRUCTURAL CONDITION OF PIPES

Technical field

[0001] This invention relates to apparatus and a method for monitoring the structural condition of a pipe. In particular, the invention relates to such techniques for use in the sub-sea oil and gas industry.

Background art

- [0002] Flexible pipes are increasingly used in the sub-sea oil and gas industry. There are considerable advantages in the cost and ease of deployment that can be obtained by using such systems. However, the movement allowed by such flexible systems also can create potential for failure of the pipe which can be both costly and dangerous. To date, there is little historical experience that the industry can use to evaluate such risks in advance and because of the serious nature of the consequences of failure, it is desirable to monitor such pipes frequently or continuously.
- [0003] The complexity of structures used in oil and gas sub-sea is increasing to satisfy the many requirements in terms of thermal behaviour, geometry, multiple fluid flows, flexibility and mechanical characteristics. For example, some umbilicals, flow lines or risers may be used to connect wells or facilities at the sea bed to sometimes floating facilities or platforms at the sea surface. Other examples of such structures include manifolds, separators and control units.
- [0004] Some systems have been proposed for detecting damage or failure in aspects of the pipe structure that could lead to catastrophic failure of the pipe if left unattended. An example of this can be found in US 7 296 480. In this case, a strain gauge rod is mounted on the side of a flexible pipe so as to measure the twist in the pipe near an end-fitting resulting from failure of one or more reinforcing plies in the pipe. A fibre optic sensor is held in place circumferentially on the pipe at various locations but is free to slide axially. In this way, twist can be measured which is the result of ply failure. This measurement, combined with gas detection can be used to detect failure.

- [0005] This system is limited in that it only measures twist at an end-fitting resulting from the failure of one or more plies.
- [0006] Various other methods have been applied to assess the integrity of flexible risers or pipes. Inspection programs have been applied which consist of visual examination, hydrostatic test and surface monitoring procedures, which may include a combination with gas detection.
- [0007] This invention aims to provide a measurement that can monitor the change in the condition of a pipe arising from the loads imposed upon it in use. It is also an object to provide a system that can be used to discriminate between the conditions of various sections of the pipe. The invention achieves these objectives by using at least one carrying apparatus to locate a transducer and so provide a reference for monitoring any changes that might occur to the condition of a pipe without the need to wait for failure to occur, as well as determining where and when failure does in fact occur.

Disclosure of the invention

- [0008] A first aspect of this invention provides apparatus for monitoring the structural condition of a pipe, comprising:
- at least one transducer carrying apparatus locatable on the outside of the pipe;
 - the transducer carrying apparatus including at least one transducer located thereon to detect a change in the condition of the pipe, along its length;
 - the transducer being both a sensor and an actuator; and
 - a signal emitted in the proximity of the transducer being detectable by the transducer, the signal representing a change in the condition of at least one component of the pipe on which the transducer is located, along its length.
- [0009] The transducer may be able to interrogate at least one structural component of the pipe in order to change a change in the condition of the pipe, along its length.
- [0010] In one form of the invention a first transducer may be able to emit a signal, the emitted signal being able to propagate through at least one component

of the pipe, along its length, and being detectable by at least a second transducer. The emitted signal may be detectable by a plurality of transducers. A portion of the emitted signal may be reflected and the reflected portion of the emitted signal may be detectable by the first transducer.

- [0011] According to the invention an attenuation of the emitted signal that is detectable by a transducer may be representative of a change in the condition of at least one component of the pipe, along its length.
- [0012] Preferably, the change in the condition of the pipe is caused by deformation of at least one component of the pipe, along its length. The change in the condition of the pipe may further be caused by the rupture, degradation, cracking, thinning, softening, hardening, splitting, corrosion or breaking of at least one component of the pipe.
- [0013] A plurality of transducers may be located on the transducer carrying apparatus. In these circumstances, more than one type of transducer may be located on the transducer carrying apparatus. Preferably, a plurality of transducer carrying apparatuses are locatable on the pipe. The transducer carrying apparatuses may be spaced apart longitudinally along the length of the pipe.
- [0014] At least one transducer may be positioned to monitor one or a group of strands of a pipe, along its length. Further, at least one transducer may be positioned to monitor one or a group of tensile armour elements of a pipe, along its length.
- [0015] In one form of the invention the transducer may be dynamic pressure transducer such as, for example, a hydrophone, a microphone, a piezoelectric transducer, a capacitance transducer, a resistance transducer, or a strain transducer. The piezoelectric transducer may be a PZT transducer.
- [0016] In another form of the invention the transducer may be a displacement transducer such as, for example, an accelerometer, a velocity transducer or a strain transducer. The velocity transducer may be a geophone type transducer.

- [0017] In a further form of the invention the transducer may be an optical transducer such as, for example, an interferometric principle transducer, an optical fibre principle transducer, a optical fibre Bragg grating principle transducer, a back scattering principle transducer, a Raman principle transducer, a Rayleigh principle transducer or a fibre laser.
- [0018] In an even further form of the invention the transducer may be an electromagnetic transducer which uses, for example, induced current, Eddy current, Foucault current, RF, microwave, an antenna, or a coil.
- [0019] The transducer carrying apparatus may extend substantially circumferentially around the pipe on which it is locatable. Preferably the transducer carrying apparatus is in the form of a collar locatable around the pipe.
- [0020] A plurality of transducers may be located on the transducer carrying apparatus such that the transducers are positioned circumferentially around the pipe.
- [0021] In a further form of the invention at least one transducer carrying apparatus may include an extension member locatable on the pipe, the extension member being extendable between itself and another transducer carrying apparatus. The extension member may extend longitudinally along the pipe. In addition, at least one transducer may be located on the extension member.
- [0022] The transducer carrying apparatus may extend substantially longitudinally along the pipe on which it is locatable.
- [0023] The pipe may be a rigid, semi-rigid or flexible pipe. Preferably the pipe is part of a sub-sea oil or gas installation. When the pipe is a flexible pipe, the signal may be emitted by the rupture of a tensile armour element or strand.
- [0024] The invention further includes at least one signal processing device to interpret the signal. The signal processing device may use one or a combination of the techniques of triangulation, phase shift, time delay, correlation, spectrum analysis, scattering analysis, echolocation or tomography.

- [0025] The signal processing device may be used for noise reduction or cancellation, and further it may also be used for locating signal point of emission or reflection.
- [0026] A second aspect of the invention provides a method of monitoring a change in the structural condition of a pipe, comprising:
- locating at least one transducer carrying apparatus on the outside of the pipe, the apparatus having at least one transducer, the transducer being both a sensor and an actuator; and
 - detecting a change in the condition of the pipe along its length by means of the transducer, a signal emitted in the proximity of the transducer being detectable by the transducer, the signal representing a change in the condition of at least one structural component of the pipe on which the transducer is located, along its length.
- [0027] The method may be performed by using apparatus according to the first aspect of the invention. Preferably a plurality of apparatuses are locatable at positions longitudinally spaced apart along the pipe. It is further particularly preferred that a plurality of transducers are located on a transducer carrying apparatus.
- [0028] According to a further aspect of the invention the method may further comprise emitting a signal by a first transducer, the signal being able to propagate through at least one component of the pipe and detecting the signal by at least a second transducer.
- [0029] The signal may be detectable by a plurality of transducers. A portion of the emitted signal may be reflected and the reflected portion of the emitted signal may be detectable by the first transducer. An attenuation of the emitted signal that is detectable by a transducer may be representative of a change in the condition of at least one component of the pipe.
- [0030] In a preferred form of the invention the change in the condition of the pipe that is detected is the rupture of a tensile armour element or strand in a flexible pipe.
- [0031] Further aspects of the invention will be apparent from the following description.

Brief description of the drawings

[0032] Figure 1 shows a schematic sub-sea system in which the present invention is applicable;

Figure 2 shows a perspective side view of apparatus for monitoring the structural condition of a pipe according to a first embodiment of the invention;

Figure 3 shows a perspective side view of apparatus for monitoring the structural condition of a pipe according to a second embodiment of the invention;

Figure 4 shows a signal pathway between a first collar and a second collar of the apparatus in Figure 3;

Figure 5 shows an extended perspective side view of the apparatus of Figures 3 and 4;

Figure 6 shows a schematic view of a third embodiment of the apparatus for monitoring the structural condition of a pipe according to the invention;

Figure 7 shows schematic view of a fourth embodiment of the apparatus for monitoring the structural condition of a pipe according to the invention;

and

Figure 8 shows a schematic view of a fifth embodiment of the apparatus for monitoring the structural condition of a pipe according to the invention.

Mode(s) for carrying out the invention

[0033] The present invention provides apparatus and methods that allow structural monitoring of pipes such as rigid, semi-rigid and flexible pipe of the types used in the sub-sea oil and gas industry. Figure 1 shows a schematic sub-sea system which comprises an FPSO vessel 10 which is anchored to the sea bed by anchor chains 12. A tanker offloading buoy 14 is connected to the FPSO 12 by means of a flexible offloading pipeline 16. Further flexible flowlines 18 connect the FPSO 10 to nearby platforms 20 to allow direct production to the FPSO. Also, existing sub-sea wells 22 have connections to sub-sea manifolds 24 from which flexible flowlines and risers 26 lead to connect to the FPSO 10. This invention allows monitoring of pipelines 16, flowlines 18 and risers 26 through which fluids flow, as well as structural pipes such as those used in the support structures of the platform 20.

- [0034] This invention is particularly concerned with monitoring a change in the condition of pipes such as flexible pipes. This is accomplished by the detection of damage, distortion or deformation of a component of the pipe. Other changes in the condition of the pipe which may also be monitored are, for example, rupture, degradation, cracking, thinning, softening, hardening, splitting or corrosion of a component of the pipe. Such monitoring can be useful to predict or detect further damage and/or failure of the pipe in sub-sea installations.
- [0035] This invention is particularly useful to monitor flexible pipes because of their complex structure. Flexible pipes normally have enforcement strands to give the assembly better longitudinal or transversal strength. The transducer or transducer array can be positioned to monitor one or a group of the enforcement strand.
- [0036] The invention is based on an apparatus configured to detect changes in the structural condition of the pipe to which it is attached, which includes any damage, distortion or deformation to the structure of the pipe or pipe components. Figure 2 shows one embodiment of the invention, comprising a collar 28 clamped around a pipe 30. Collar 28 may be, for example, formed from two semi-circular rings joined by means of a hinge (not shown) on one side and a connector (not shown) on the other. Collar 28 provides a plurality of transducers 32.
- [0037] As is discussed below, the number and arrangement of transducers 32 can be selected according to operational requirements. Different types of transducers can be used and in addition, these different types of transducers may be arranged in different ways. A preferred form of transducers 32 is a series of acoustic transducers. These transducers 32 preferably each include both a sensor and an actuator. This dual capacity of the transducer devices enable each to act both as a sensor in order to passively monitor and detect a change to the structural condition of the pipe 30, and as an interrogator in order to actively monitor and detect a change to the structural condition of pipe 30.
- [0038] The invention can be used to detect events in the pipe, along its length that can compromise the condition of the pipe. Such events could include,

for example, the rupture of a metal strand in one of the cables which make up part of the structure of the pipe. In this example, the rupture itself can generate a signal such as an acoustic signal, or the rupture can be detected by a signal emitted by one of the transducers and sensed by one of the transducers. In the case of an acoustic signals being used, the rupture may cause a change in the acoustic impedance of the section of pipe that is being monitored. This change of impedance could be detected by an increase in signal scattering or an increase in time of flight of impulsions in the signal, by using tomographic techniques, spectrum analysis, frequency sweeps or any other technique which can detect a change in a signal. The event could also be located by, for example, using time of flight, echolocation, using the transducers as a phased array, or other such methods.

[0039] In certain instances when the invention is used to detect events in the pipe which may compromise the condition of the pipe, it may be advantageous to incorporate different types of transducers so as to differentiate between events which may not relate to the condition of the pipe and those which do relate to the condition of the pipe. It may thus, for example, be advantageous to use an acoustic transducer in combination with a transducer for torsion and/or a transducer for acceleration, in these instances. In this way if an acoustic transducer detects an acoustic signal resulting from a breakage of a strand or tensile armour element of a flexible pipe, a torsion transducer can be used at the same time to detect whether or not a significant torsion force has been exerted on the pipe. This allows the operator assessing the information to decide whether a significant deterioration of the structural condition of the pipe has occurred or not.

[0040] In the case of an acoustic transducer 32 acting as an interrogator in order to actively detect a change in the condition of pipe 30 along its length and using the method of reflection, a particular transducer performs both a sending and receiving of pulsed waves as the transmitted "sound" is reflected back to the device. The reflected sound may come from an interface such as an imperfection within the object. A diagnostic machine

used to interpret the results may then, for example, display these results in the form of a signal with amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection.

- [0041] When the transducer 32 uses the method of attenuation (or through-transmission) mode, the transmitter portion of transducer 32 sends a signal of sound waves through the surface of a structural component or components of pipe 30 which are being monitored and a separate receiver in another transducer 32 detects the amount that has reached it on another surface after travelling through the structural component(s). Imperfections or other conditions such as a rupture in the space between the transducer which transmitted the signal and the transducer acting as the receiver reduce the amount the amount of sound transmitted, thus revealing their presence.
- [0042] The typical structure of a flexible pipe includes various layers of different materials having differing functions and characteristics. The innermost part of the flexible pipe is typically comprised of an interlocked steel carcass which resists hydrostatic pressure to radial compression during installation and supports the inner polymer sheath. The next part of the flexible pipe is this polymer sheath, preferably thermoplastic, which promotes sealing and prevents internal fluids from permeating to the external layers.
- [0043] Above this inner polymer sheath there is an interlocked steel pressure layer which provides resistance to internal and hydrostatic pressure, as well as to radial compression. This layer is preferably manufactured with carbon steel.
- [0044] Typically there is a double cross-wound tensile armour or strand layer located above the interlocked steel pressure layer which provides resistance to axial forces, to internal pressure and to torsion. Externally to the double cross-wound armour or strand layer there is then an external polymer sheath, also preferably thermoplastic. This external polymer sheath protects the internal layers against external agents which could cause corrosion and abrasion, and maintains the double cross-wound

tensile armours in a tied position and assures the sealing of the internal structure of the pipe from the external environment.

[0045] The composition of some flexible pipes may include further layers other than those described above.

[0046] The first embodiment of the invention shown in Figure 2 comprises a series of passive acoustic transducers located on a single collar 28. In this case, acoustic transducers 32 are spaced apart and located circumferentially around pipe 30 on collar 28. Each of the transducers 32 is preferably located so that it is in the proximity of one of the tensile armour elements or strands of the double cross-wound tensile armour layer of pipe 30. The change in the condition of a tensile armour element or strand due to damage, distortion or deformation of the tensile armour element, which is in the proximity of collar 28 causes a sound to be emitted and one or more transducers 32 which are located nearest that tensile armour element are then able to detect the sound emitted and translate this sound into a signal. This signal can then be forwarded to a signal processor and analysed using signal processing techniques.

[0047] The second embodiment of the invention shown in Figures 3, 4 and 5 each comprises a series of active acoustic transducers located on spaced apart collars 28 along the length of a pipe 30. Each of the transducers 32 is also preferably located on a pipe 30 so that it is in the proximity of one of the tensile armour elements of the double cross-wound tensile armour layer of pipe 30. The transducers 32 in one of the collars 28 can typically send an acoustic signal which is then detected by transducers 32 in another spaced apart collar 28. In this way transducers 32 are able to interrogate parts of structural elements of pipe 30 which are located in the region between them along the length of the pipe. Changes in the condition of a tensile armour element or strand, such as deformation, in the region between the two collars 28 causes a change in the characteristics of the transmitted sound signal and the transducers 32 are able to detect a change in the signal. The changes detected in the signal may be either from a reflection of the transmitted signal or an attenuation of the transmitted signal. Several transmitted and received signals can

then be processed using signal processing techniques and an acoustic tomography produced. The deformation, distortion or damage which has caused a change in a component of the pipe 30 may then be analysed. Pipe 30 may then be monitored further over time if required in order to predict possible further damage, distortion or breakage.

[0048] An example of the path which a transmitted sound signal is most likely to follow is shown in Figure 4. The path follows along a part of the curve of one of the tensile armour elements as it winds its way around the outer layers of the pipe in a cross-wound pitch and along its length. The acoustic transducers 32 located downstream of the deformation are then able to detect a change to the characteristics of the standard signal which is received from an undamaged tensile armour element. A number of signals transmitted and or received can be used to show an acoustic tomography of the tensile armour element of interest by using various signal processing techniques, and the deformation or damage detected can then be analysed.

[0049] In Figure 5 a plurality of collars 28 are shown spaced apart longitudinally along pipe 30. Each of these collars 28 have transducers 32 located thereon which may act as both transmitters and receivers to detect and report on acoustic signals arising from the deformation to a tensile armour member of the pipe 30, which is located in the region between two consecutive collars 28.

[0050] Figure 6 shows the third embodiment of the invention to comprise a single collar 28 having a series of acoustic transducers located thereon which are spaced apart and located circumferentially around pipe 30. There are two rows of circumferentially spaced apart acoustic transducers. The first row is made up of acoustic transmitters 34 and the second row is made up of acoustic receivers 36. Collar 28 in this embodiment is moveable along the length of the pipe 30. Pipe 30 is monitored by scanning and interrogating the pipe using a step by step method of scanning and interrogation. The acoustic transmitters 34 are used to transmit an acoustic signal which is shortly thereafter received by the acoustic receivers 36. Collar 28 is then moved to the next position along pipe 30.

Acoustic transmitters 34 then again transmit an acoustic signal which is shortly thereafter received by acoustic receivers 36.

- [0051] Deformation of a tensile armour element in the region on pipe 30 between the acoustic transmitters 34 and acoustic receivers 36 of collar 28 causes a change to occur to the acoustic signal transmitted by transmitters 34. The acoustic receivers 36 located in proximity to the deformation are then able to detect a change in the characteristics of the transmitted signal which they receive. A number of signals transmitted and received can be used to show an acoustic tomography of the tensile armour element of interest by using various signal processing techniques, and the deformation or damage to the tensile armour element can then be analysed.
- [0052] The fourth embodiment of the invention is shown in Figure 7 to comprise a plurality of collars 28 located on pipe 30. Only one acoustic transducer 32 is located on each of the collars 28. Each acoustic transducer 32 is both a transmitter and receiver, able to transmit and receive acoustic signals. As described above a deformation of the structure of pipe 30 which is in the region between two collars 28 may be detected by a change occurring to the characteristics of an acoustic signal transmitted by at least one of transducers 32. A number of signals transmitted and received can be used to show an acoustic tomography of a tensile armour element of pipe 30 of interest by using various signal processing techniques, and the deformation or damage to the tensile armour element can then be analysed.
- [0053] In Figure 8 the fifth embodiment of the invention is shown to comprise an arrangement of two collars 28 located on pipe 30, the collars 28 having a transducer support 38 between them that extends longitudinally along pipe 30. Each acoustic transducer 32 is both a transmitter and receiver, able to transmit and receive acoustic signals. As described above a deformation of the structure of pipe 30 which is in the region between two collars 28 may be detected by a change occurring to the characteristics of an acoustic signal transmitted by at least one of transducers 32. A number of signals transmitted and received can be used to show an acoustic

tomography of a tensile armour element of pipe 30 of interest by using various signal processing techniques, and the deformation or damage to the tensile armour element can then be analysed.

- [0054] In a further embodiment of the invention (not shown) the transducer carrying apparatus may itself be a longitudinal member which extends substantially longitudinally along the pipe 30 on which it is locatable. In this form of the invention a plurality of transducers may be locatable along its length at required intervals and thus at intervals along the length of the pipe.
- [0055] As discussed above, in alternative forms of the invention other types of transducers may be used. An example of another type of transducer that may be used is a dynamic pressure transducer such as, for example, a hydrophone, a microphone, a piezoelectric transducer, a capacitance transducer, a resistance transducer, or a strain transducer. The piezoelectric transducer may be a PZT transducer.
- [0056] The transducer may also be a displacement transducer such as, for example, an accelerometer, a velocity transducer or a strain transducer. The velocity transducer may be a geophone type transducer.
- [0057] Further, the transducer may be an optical transducer such as, for example, an interferometric principle transducer, an optical fibre principle transducer, an optical fibre Bragg grating principle transducer, a back scattering principle transducer, a Raman principle transducer, or a Rayleigh principle transducer.
- [0058] Even further the transducer may be an electromagnetic transducer which uses, for example, induced current, Eddy current, Foucault current, RF, microwave, an antenna, or a coil.
- [0059] Because the apparatus of the invention can be retroactively applied to a pipe, it can be fixed in any location where changes to the condition of the pipe are likely to occur as a result of the pipe being under a load. Furthermore, multiple installations or variations of multiple installations can be provided on any given pipe in different locations. This approach can assist in cases where it is not possible to instrument directly a region of the pipe of interest, outputs from offset installations being used to

interpolate or extrapolate parameters to the inaccessible regions. Also, it is possible to monitor different parts of the pipe having different load strengths and so cross-reference readings from other locations.

- [0060] In all cases, each apparatus installation is effectively a stand-alone monitoring apparatus and can feed back its readings to a data acquisition and analysis unit located at the surface in the usual manner. Alternatively, a memory can be provided which can accumulate data which in turn can be downloaded by a reader unit that is brought into close proximity to the transducers.
- [0061] The apparatus of the invention further includes one or more signal processing devices which may be used to interpret the signal. These devices may be located on or remote from the transducer carrying apparatus or collar. The devices may use one or a combination of the techniques such as, for example, triangulation, phase shift, time delay, correlation, spectrum analysis, scattering analysis, echolocation, tomography in order to interpret the signal received.
- [0062] The signal processing may be used for noise reduction or cancellation, and further it may also be used for locating signal point of emission or reflection.
- [0063] This invention is particularly useful to monitor flexible pipes because of their complex structure. Flexible pipes normally have enforcement strands to give the assembly better longitudinal or transversal strength. The transducer or array of transducers can be positioned to monitor one of a group of enforcement strands.
- [0064] While monitoring the change in the condition of flexible pipes is of particular interest, similar effects can also be monitored in rigid and semi-rigid pipes.

Claims

1. Apparatus for monitoring the structural condition of a pipe, comprising:
 - at least one transducer carrying apparatus locatable on the outside of the pipe;
 - the transducer carrying apparatus including at least one transducer located thereon to detect a change in the condition of the pipe, along its length;
 - the transducer being both a sensor and an actuator; and
 - a signal emitted in the proximity of the transducer being detectable by the transducer, the signal representing a change in the condition of at least one component of the pipe on which the transducer is located, along its length.
2. Apparatus as claimed in claim 1, wherein the transducer is able to interrogate at least one structural component of the pipe in order to detect a change in the condition of the pipe, along its length.
3. Apparatus as claimed in claim 1 or 2, wherein at least one transducer is positioned to monitor one or a group of strands or tensile armour elements of a pipe, along its length.
4. Apparatus as claimed in claim 3, wherein the transducer is dynamic pressure transducer comprising a hydrophone, a microphone, a piezoelectric transducer, a capacitance transducer, a resistance transducer, or a strain transducer.
5. Apparatus as claimed in claim 4, wherein the transducer is a PZT piezoelectric transducer.
6. Apparatus as claimed in any of claims 1 to 3, wherein the transducer is a displacement transducer comprising an accelerometer, a velocity transducer or a strain transducer.
7. Apparatus as claimed in claim 6, wherein the transducer is a geophone type velocity transducer.
8. Apparatus as claimed in any of claims 1 to 3, wherein the transducer is an optical transducer comprising an interferometric principle transducer, an optical fibre principle transducer, a optical fibre Bragg grating principle transducer, a back scattering principle transducer, a Raman principle transducer, a Rayleigh principle transducer, or a fibre laser.

9. Apparatus as claimed in any of claims 1 to 3, wherein the transducer is an electromagnetic transducer which uses induced current, Eddy current, Foucault current, RF, microwave, an antenna, or a coil.
10. Apparatus as claimed in any preceding claim, wherein a plurality of transducers are located on a transducer carrying apparatus.
11. Apparatus as claimed in claim 10, wherein more than one type of transducer is located on the transducer carrying apparatus.
12. Apparatus as claimed in claim 10 or 11, wherein the transducer carrying apparatus extends substantially circumferentially around the pipe on which it is locatable.
13. Apparatus as claimed in claim 12, wherein the transducer carrying apparatus is in the form of a collar locatable around the pipe.
14. Apparatus as claimed in any of claims 10-13, wherein a plurality of transducer carrying apparatuses are locatable on the pipe.
15. Apparatus as claimed in claim 14 wherein the transducer carrying apparatuses are spaced apart longitudinally along the length of the pipe.
16. Apparatus as claimed in claim 14 or 15, wherein a plurality of transducers are located on the transducer carrying apparatus such that the transducers are positioned circumferentially around the pipe.
17. Apparatus as claimed in any of claims 14 to 16, wherein at least one transducer carrying apparatus includes an extension member locatable on the pipe, the extension member being extendable between itself and another transducer carrying apparatus.
18. Apparatus as claimed in claim 17, wherein the extension member extends longitudinally along the pipe.
19. Apparatus as claimed in claim 17 or 18, wherein at least one transducer is located on the extension member.
20. Apparatus as claimed in any of claims 10-19, wherein the transducer carrying apparatus extends substantially longitudinally along the pipe on which it is locatable.
21. Apparatus as claimed in any of the preceding claims, which further includes at least one signal processing device to interpret the signal.

22. Apparatus as claimed in claim 21, wherein the signal processing device uses one or a combination of the techniques of triangulation, phase shift, time delay, correlation, spectrum analysis, scattering analysis, echolocation or tomography.
23. Apparatus as claimed in claim 21 or 22, wherein the signal processing device is used for noise reduction or cancellation.
24. Apparatus as claimed in claims 21, 22 or 23, wherein the signal processing device is used for locating signal point of emission or reflection.
25. A method of monitoring a change in the structural condition of a pipe, comprising:
- locating at least one transducer carrying apparatus on the outside of the pipe, the apparatus having at least one transducer, the transducer being both a sensor and an actuator; and
 - detecting a change in the condition of the pipe along its length by means of the transducer, a signal emitted in the proximity of the transducer being detectable by the transducer, the signal representing a change in the condition of at least one structural component of the pipe on which the transducer is located, along its length.
26. A method as claimed in claim 25, which further comprises emitting a signal by a first transducer, the signal being able to propagate through at least one component of the pipe, and detecting the signal by at least a second transducer.
27. A method as claimed in claim 26, comprising detecting the signal by a plurality of transducers.
28. A method as claimed in claim 26 or 27, wherein a portion of the emitted signal is reflected, the method comprising detecting the reflected portion of the emitted signal by the first transducer.
29. A method as claimed in any of claims 26 to 28, comprising measuring attenuation of the emitted signal that is detected by a transducer as representative of a change in the condition of at least one component of the pipe.
30. A method as claimed in claim 29, wherein the change in the condition of the pipe is the rupture of a tensile armour element or a strand in a flexible pipe.

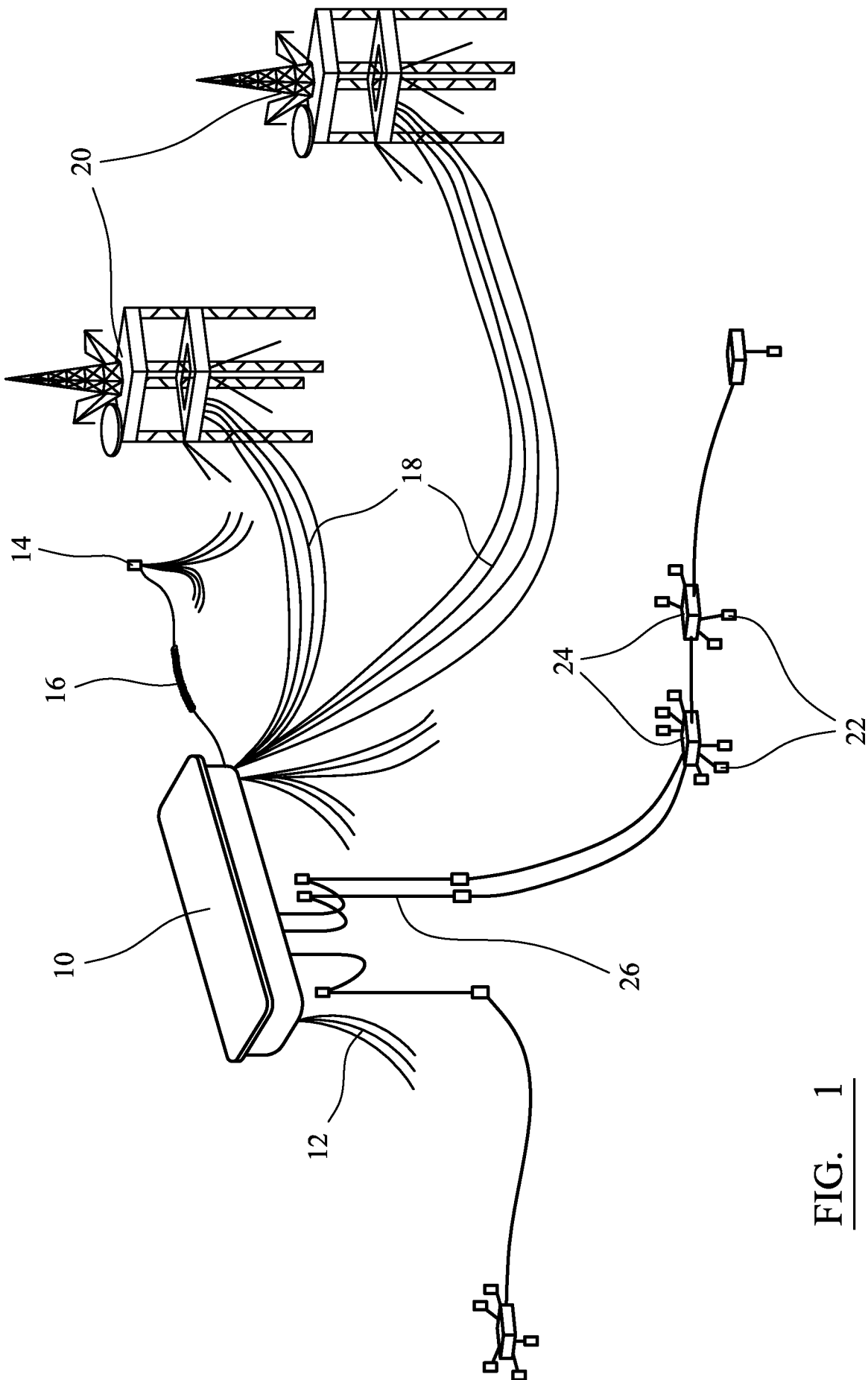


FIG. 1

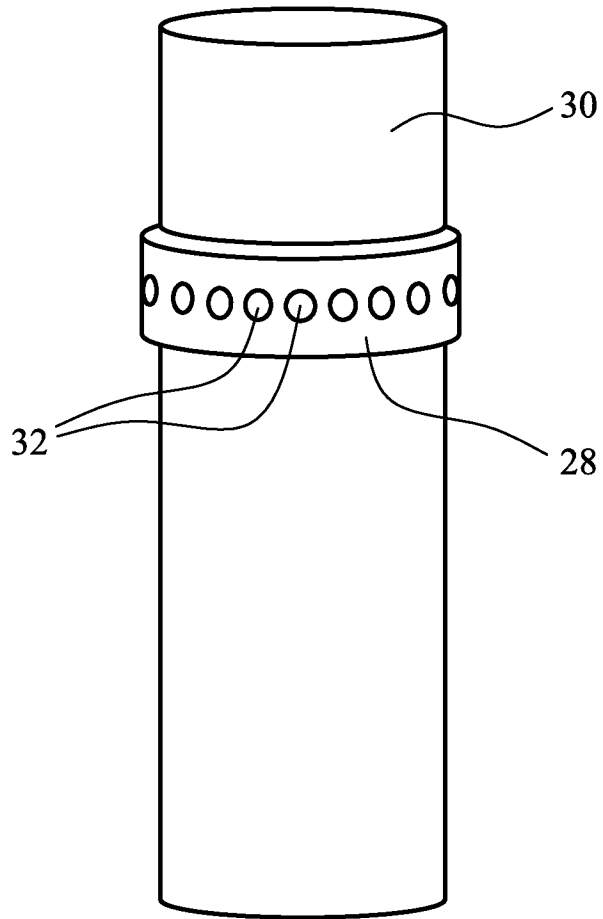


FIG. 2

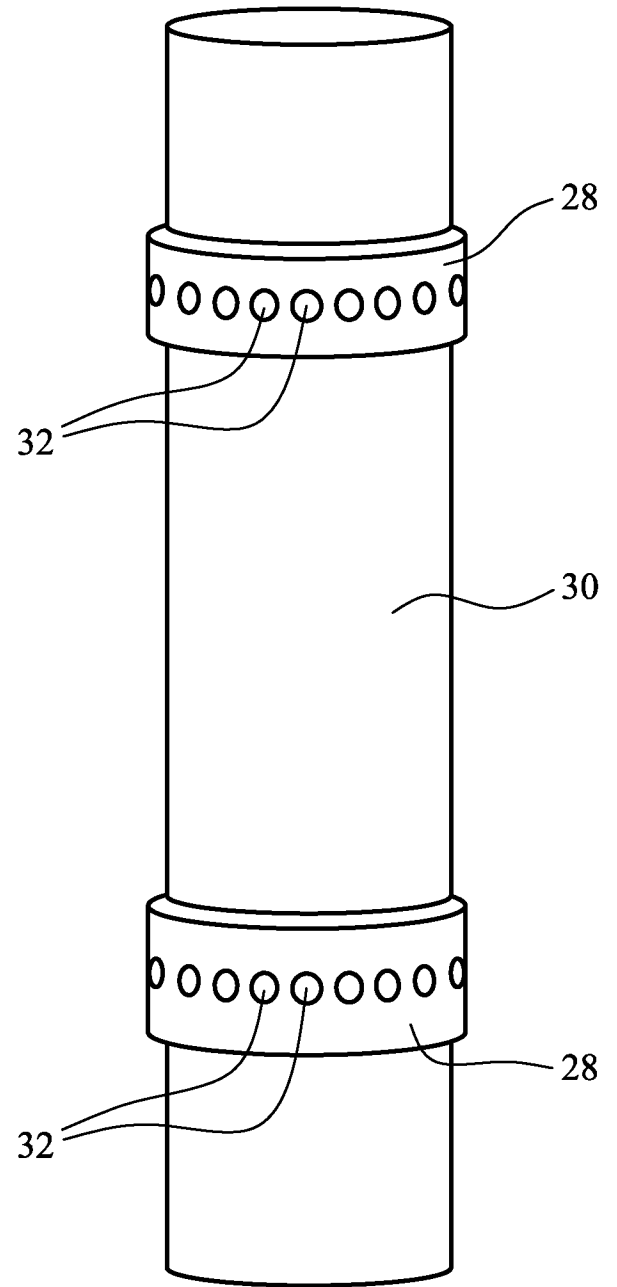


FIG. 3

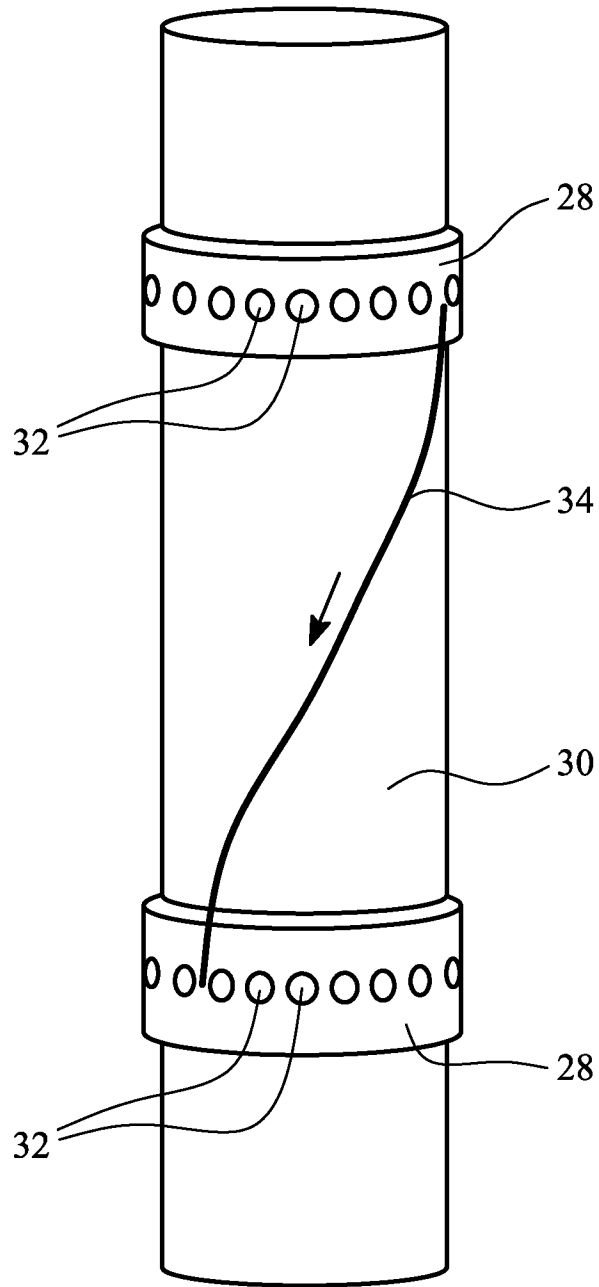


FIG. 4

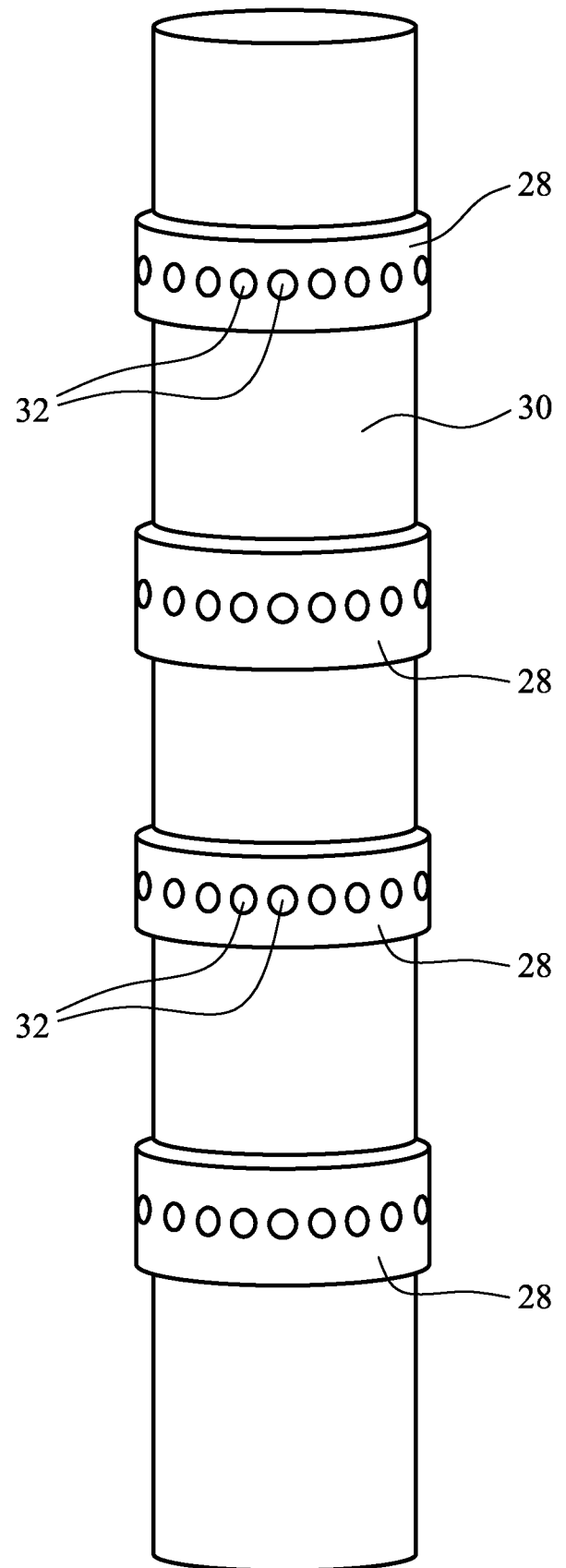


FIG. 5

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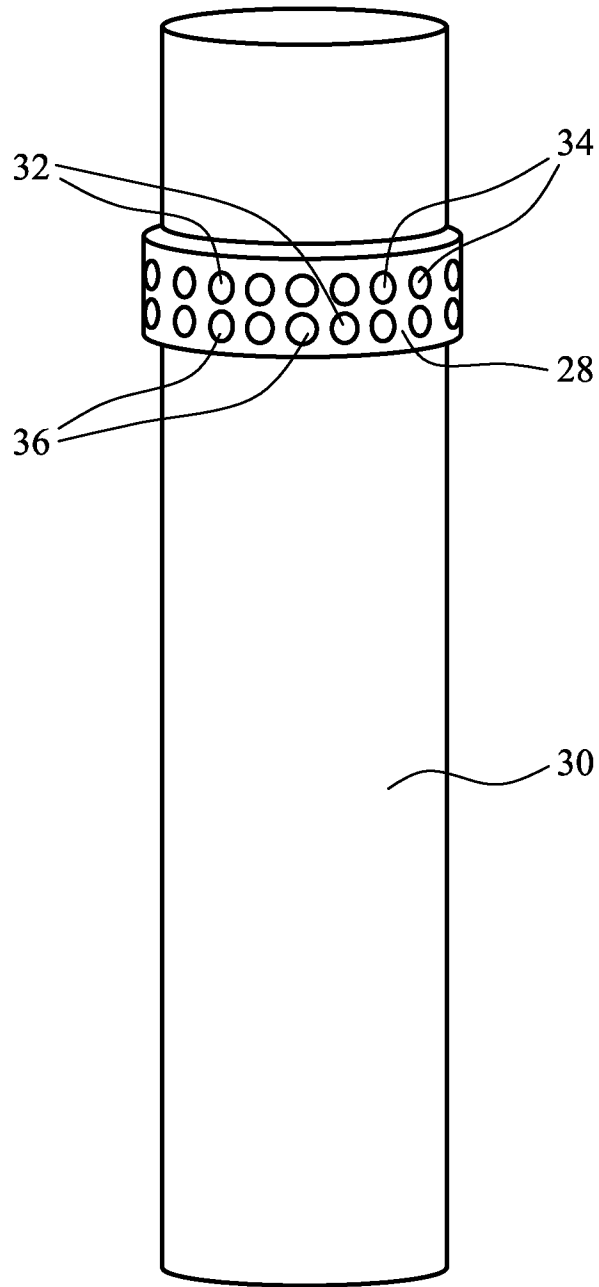


FIG. 6

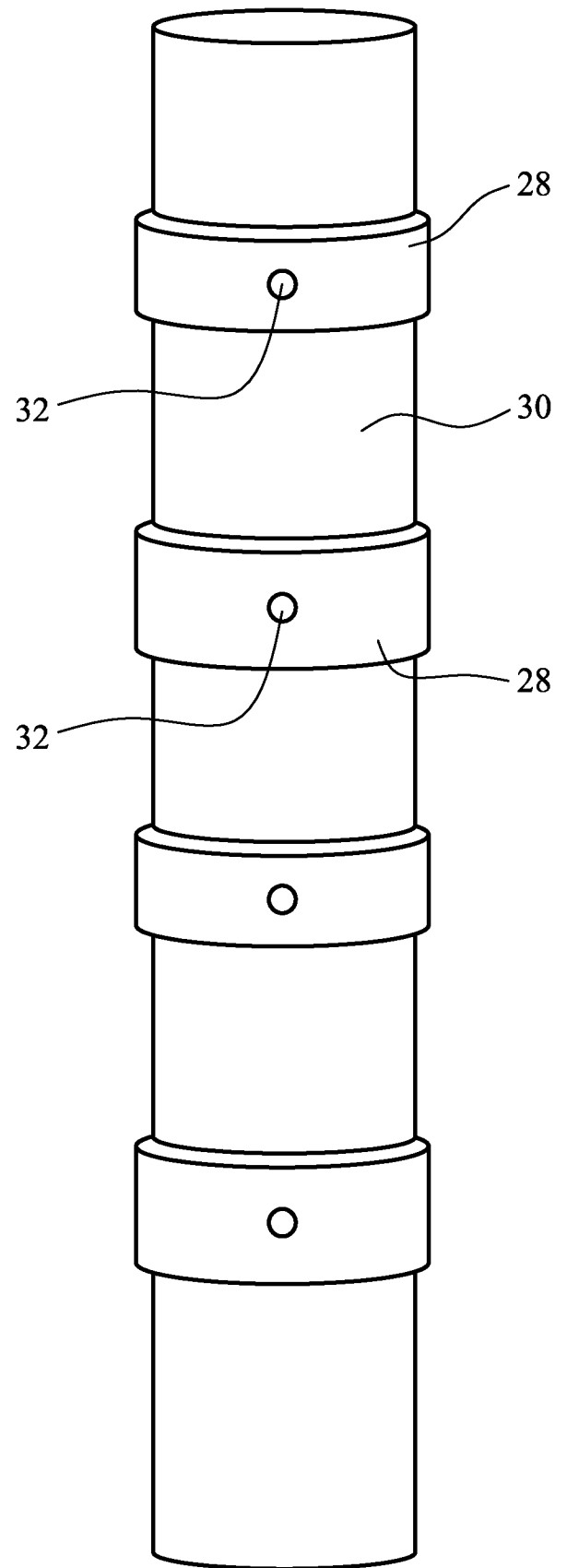


FIG. 7

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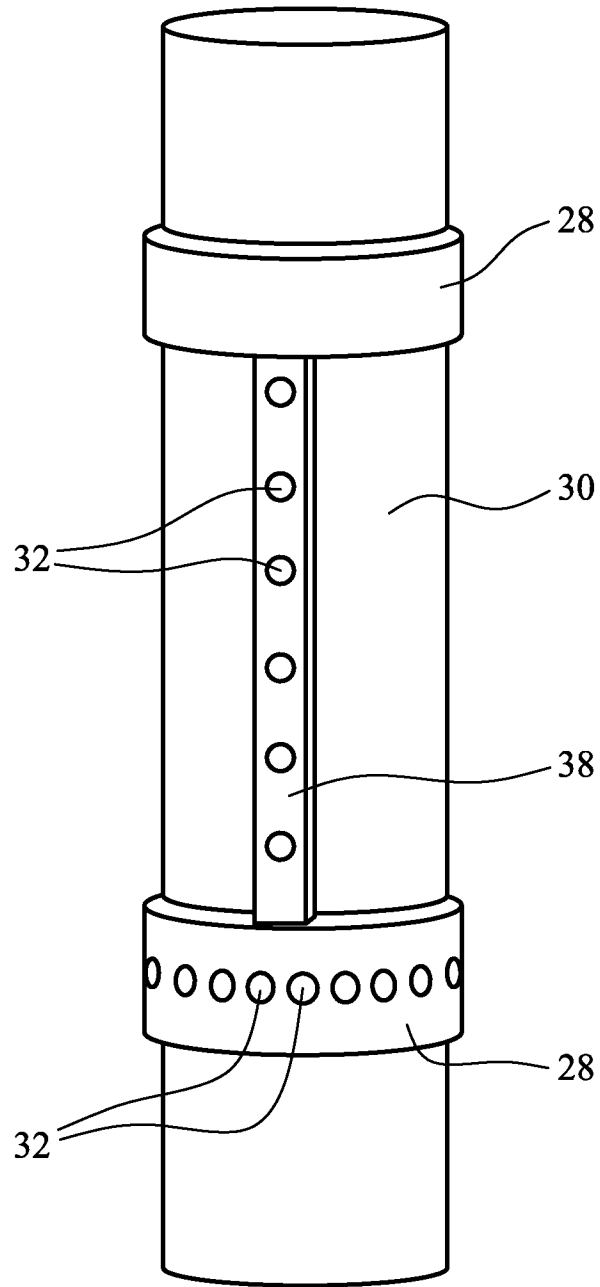


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2009/050892

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01M3/00 F17D5/00

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)
F17D G01M

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 practical, 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.
Y	US 2005/210961 A1 (DE AQUINO ROBERTO J [BR] DE AQUINO ROBERTO JOURDAN [BR]) 29 September 2005 (2005-09-29) cited in the application the whole document	1-30
Y	US 5 656 779 A (BRONOWICKI ALLEN J [US]) 12 August 1997 (1997-08-12) cited in the application abstract figure 1 column 2, line 36 - line 62 claims 1-15	1-30
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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O document referring to an oral disclosure, use, exhibition or other means

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

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X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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* & * document member of the same patent family

Date of the actual completion of the international search

22 September 2009

Date of mailing of the international search report

08/10/2009

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

Daman, Marcel

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2009/050892

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 802 143 A (SMITH ROBERT D [US]) 31 January 1989 (1989-01-31) abstract figures 1-6 column 6, line 63 - column 9, line 38 claims 1-18 -----	1-30
A	US 5 176 025 A (BUTTS NICHOLAS E [CA]) 5 January 1993 (1993-01-05) abstract figures 1-8 claims 1-5 -----	1-30
A	US 6 171 025 B1 (LANGNER CARL GOTTLIEB [US] ET AL) 9 January 2001 (2001-01-09) abstract figures 1-4 claim 1 -----	1-30

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2009/050892

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