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(54) **DOWNHOLE TELEMETRY SYSTEM USING AN OPTICALLY TRANSMISSIVE FLUID MEDIA AND METHOD FOR USE OF SAME**

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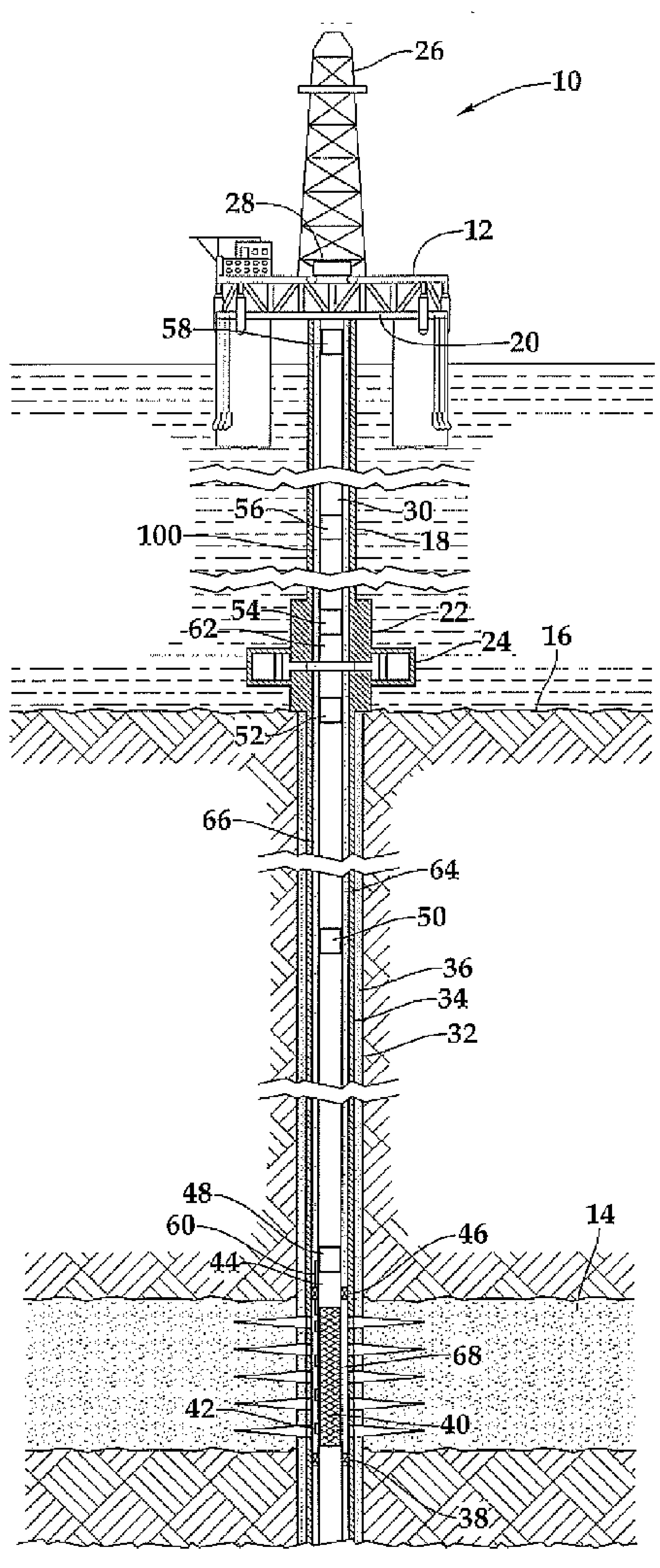
(57) **ABSTRACT**

A downhole telemetry system (**10**) disposed within a wellbore (**32**). The downhole telemetry system (**10**) includes a downhole transmitter (**48**) operable to optically transmit a data stream and a downhole receiver (**52**) operable to receive the optically transmitted data stream. An optically transmissive fluid (**64**) is disposed in the wellbore (**32**) and provides a medium for the optical transmission of the data stream between the downhole transmitter (**48**) and the downhole receiver (**52**).



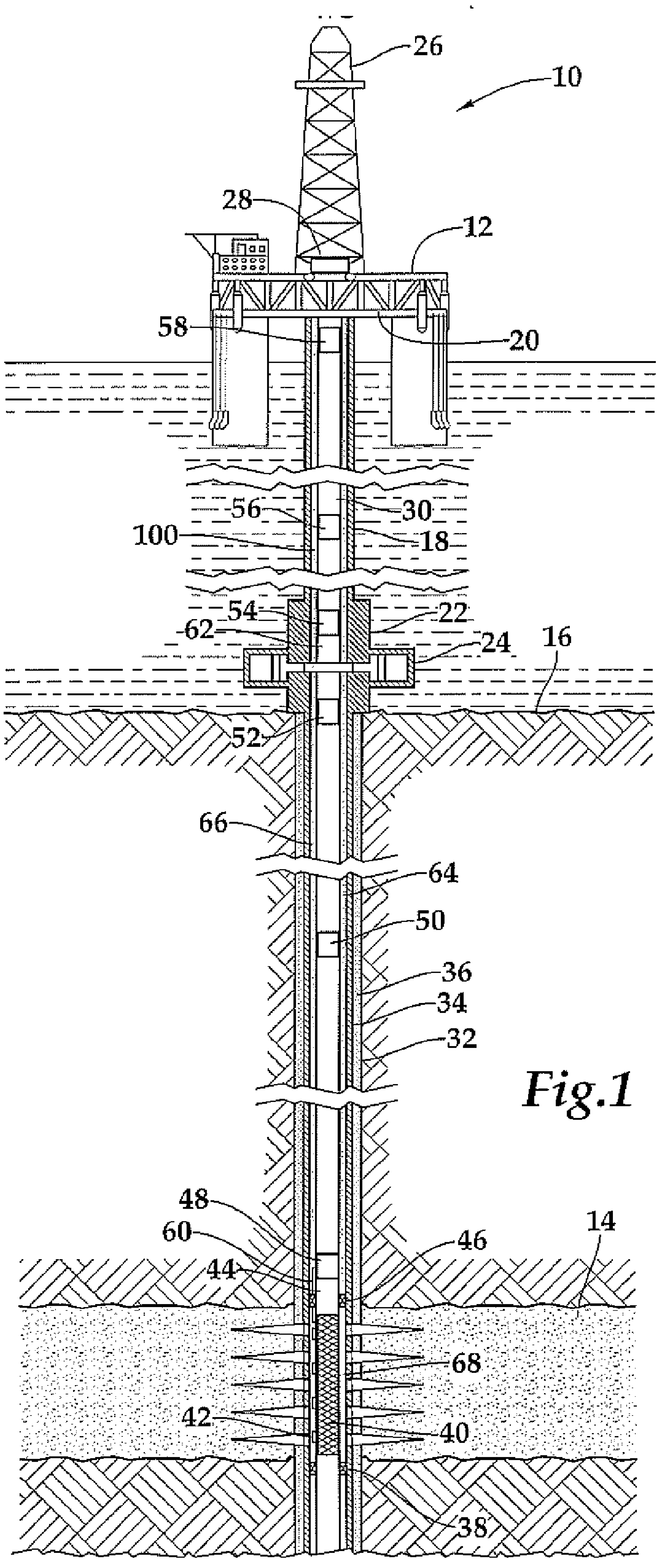

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Fig.1

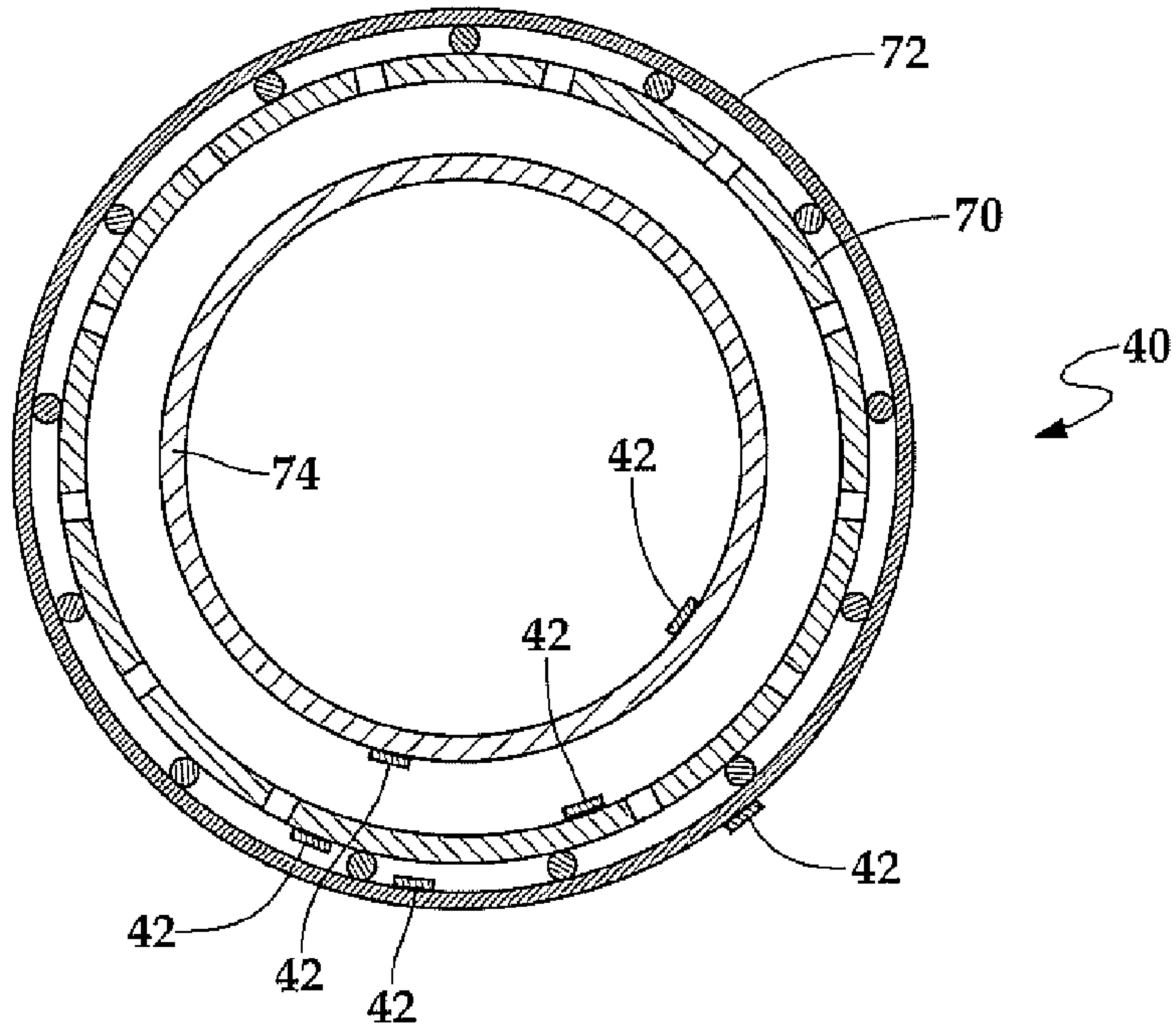

Fig.2

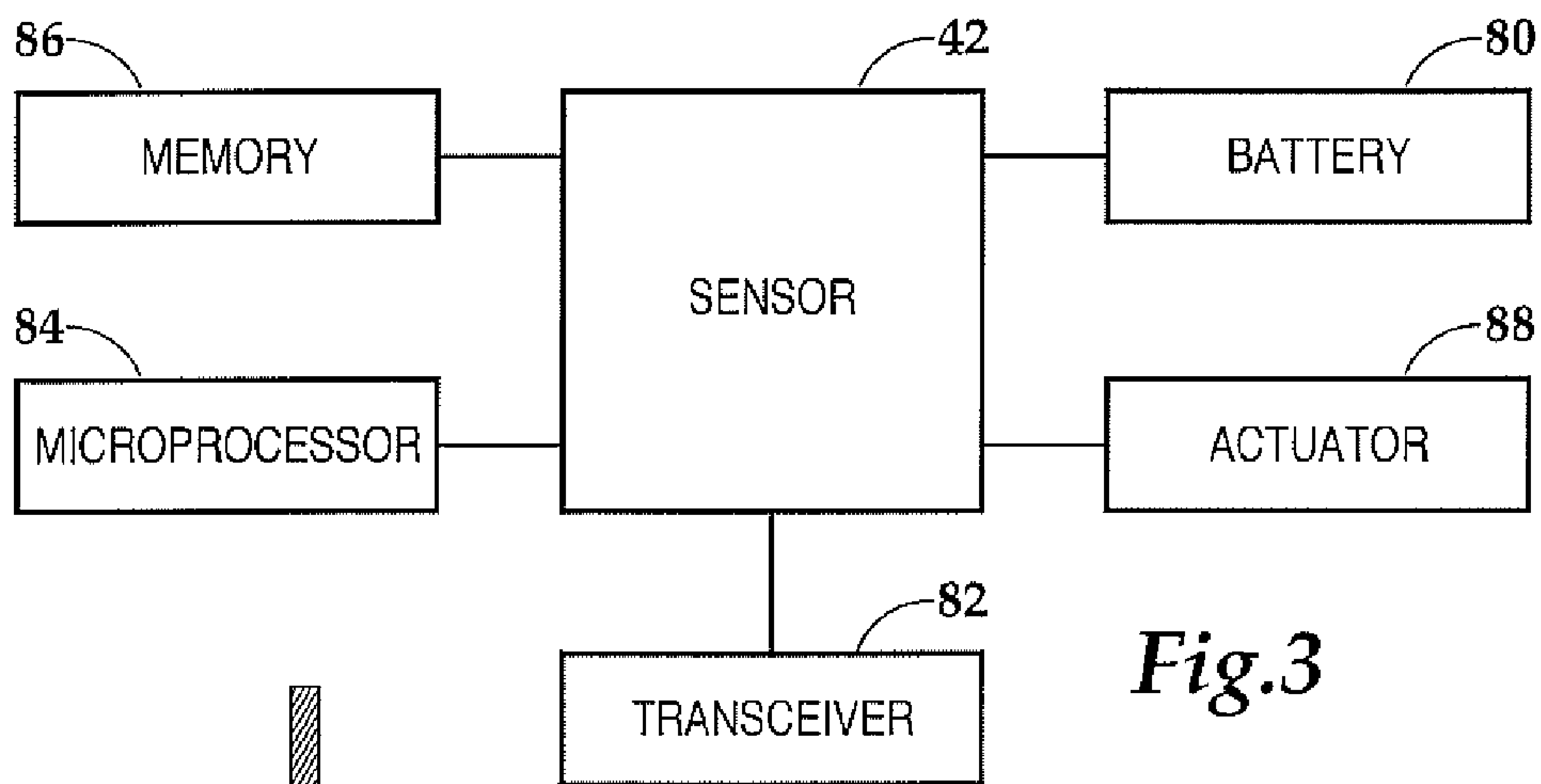

Fig.3

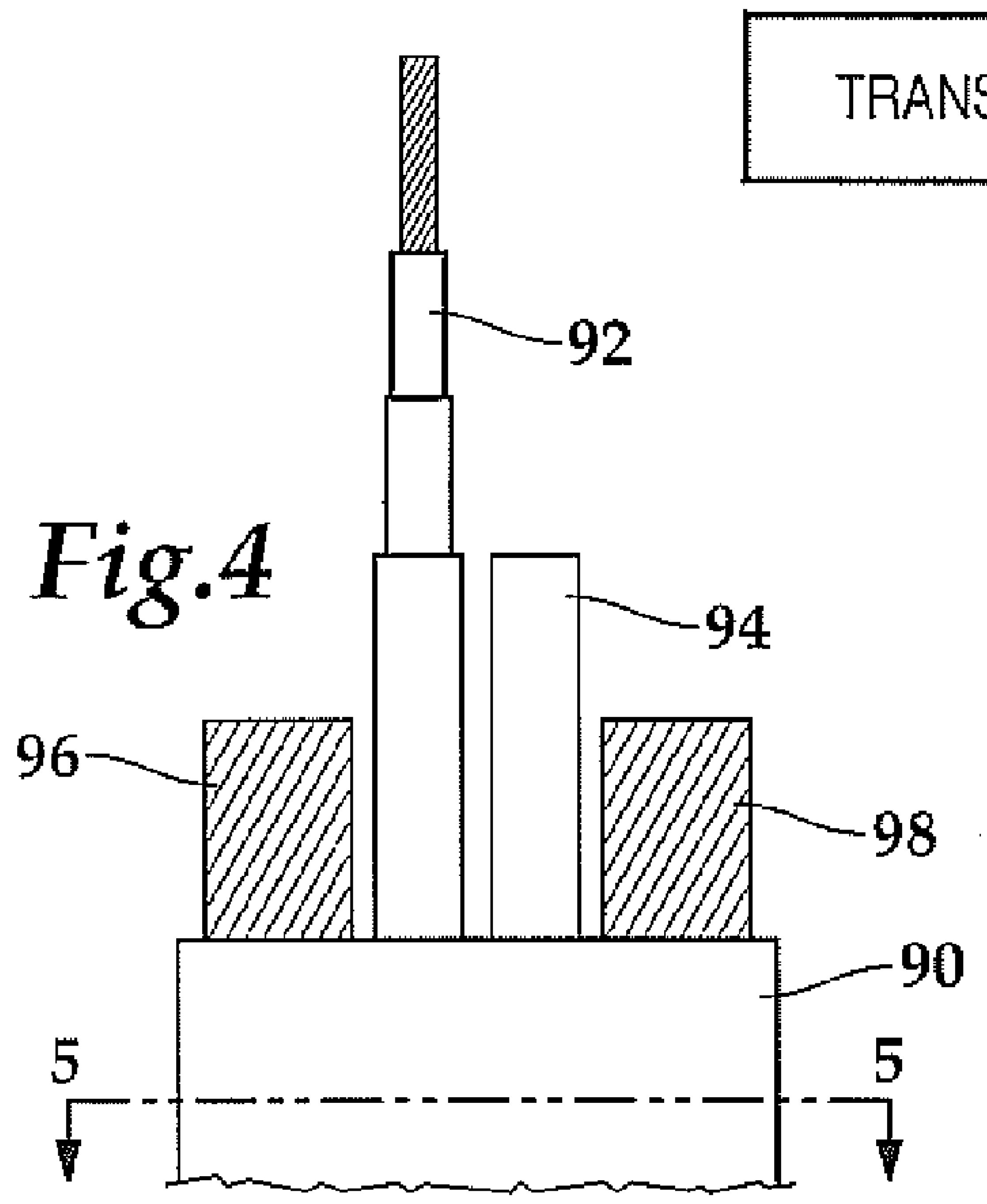

Fig.4

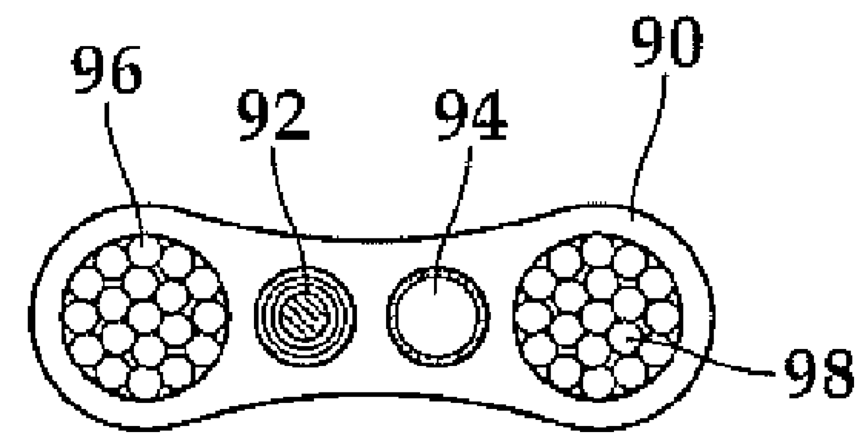

Fig.5

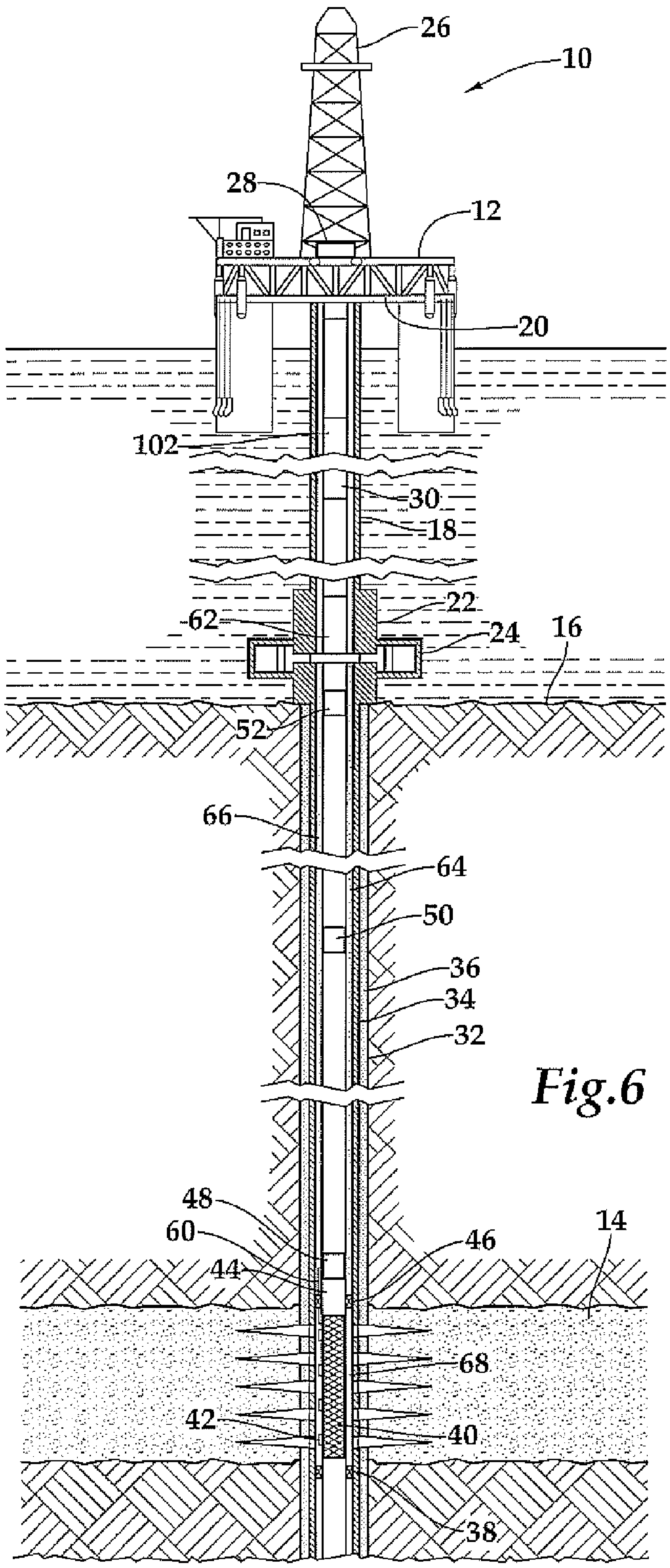
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Fig.6

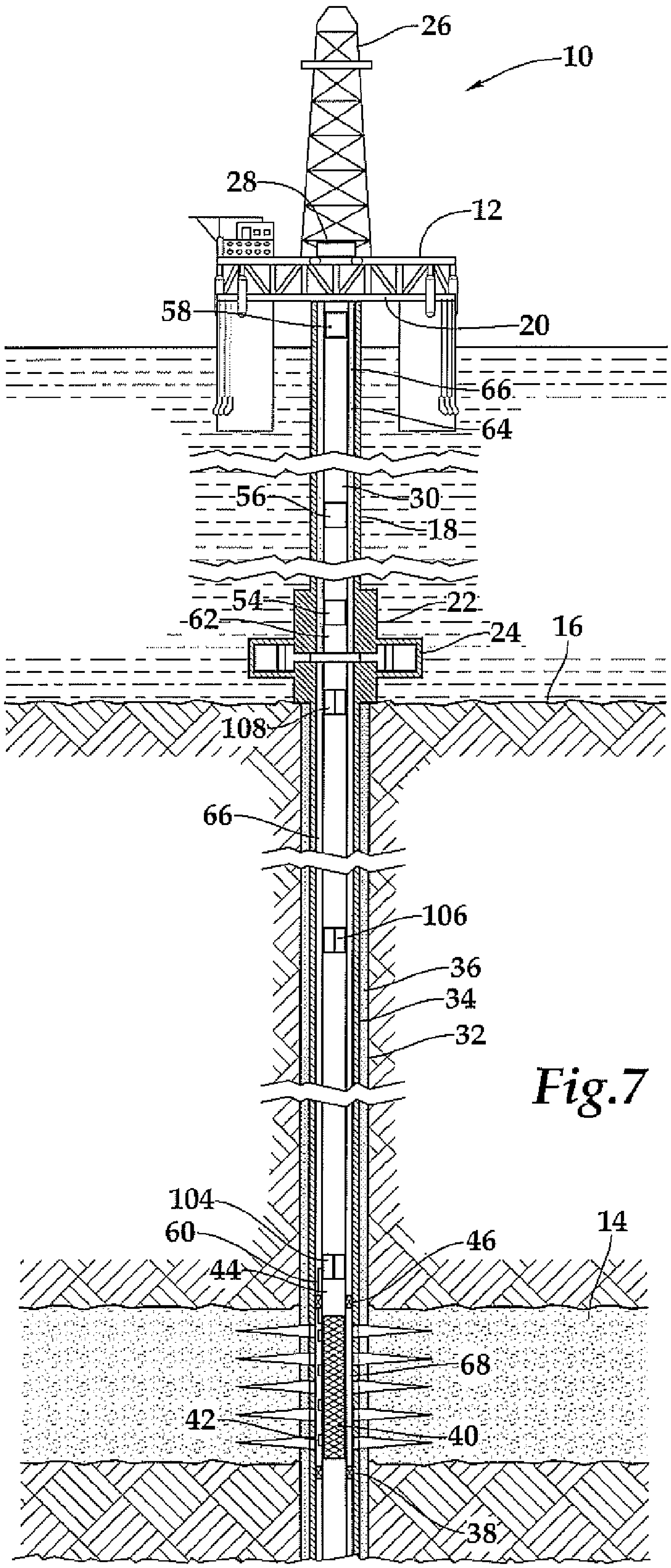
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Fig.7

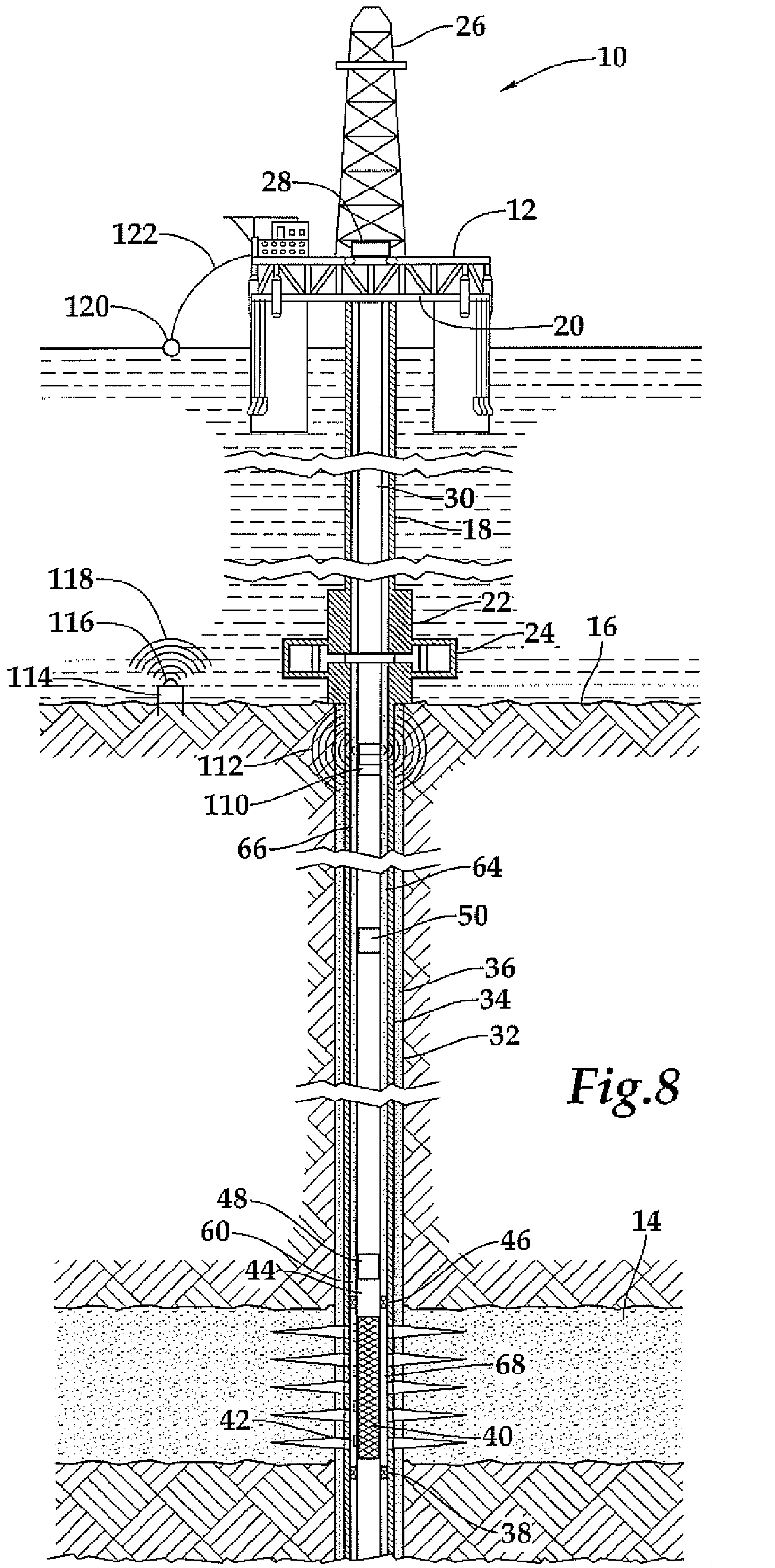
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Fig.8

DOWNHOLE TELEMETRY SYSTEM USING AN OPTICALLY TRANSMISSIVE FLUID MEDIA AND METHOD FOR USE OF SAME

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates, in general, to communication systems for transmitting data between downhole equipment and surface equipment and, in particular, to a downhole telemetry system that transmits optical signals via an optically transmissive fluid media disposed in a wellbore.

BACKGROUND OF THE INVENTION

[0002] Without limiting the scope of the present invention, its background is described with reference to sand control completions, as an example.

[0003] It is well known in the subterranean well drilling and completion art that relatively fine particulate materials may be produced during the production of hydrocarbons from a well that traverses an unconsolidated or loosely consolidated formation. Numerous problems may occur as a result of the production of such particulate. For example, the particulate causes abrasive wear to components within the well, such as tubing, flow control devices, safety devices and the like. In addition, the particulate may partially or fully clog the well creating the need for an expensive workover. Also, if the particulate matter is produced to the surface, it must be removed from the hydrocarbon fluids using surface processing equipment.

[0004] One method for preventing the production of such particulate material is to gravel pack the well adjacent to the unconsolidated or loosely consolidated production interval. In a typical gravel pack completion, a sand control screen is lowered into the wellbore on a work string to a position proximate the desired production interval. A fluid slurry including a liquid carrier and a relatively coarse particulate material, such as sand, gravel or proppants, which are typically sized and graded and which are typically referred to herein as gravel, is then pumped down the work string and into the well annulus formed between the sand control screen and the perforated well casing or open hole production zone.

[0005] The liquid carrier either flows into the formation or returns to the surface by flowing through a wash pipe or both. In either case, the gravel is deposited around the sand control screen to form the gravel pack, which is highly permeable to the flow of hydrocarbon fluids but blocks the flow of the fine particulate materials carried in the hydrocarbon fluids. As such, gravel packs can successfully prevent the problems associated with the production of these particulate materials from the formation.

[0006] In other cases, it may be desirable to stimulate the formation by, for example, performing a formation fracturing and propping operation prior to or simultaneously with the gravel packing operation. This type of treatment process is commonly referred to as a frac pack. During this treatment process, hydraulic fractures are created in the hydrocarbon bearing formation, which increase the permeability of the formation adjacent the wellbore. According to conventional practice, a fracture fluid such as water, oil, oil/water emulsion, gelled water or gelled oil is pumped down the work string with sufficient volume and pressure to open multiple fractures in the production interval. The fracture fluid may carry a suitable propping agent, such as sand, gravel or proppants, which are typically referred to herein as proppants, into the fractures for the purpose of holding the fractures open following the fracturing operation. In addition, these proppants are deposited around the sand control screen to form the gravel pack as described above. As such, frac packs can successfully enhance fluid production from the formation while also preventing the production of particulate materials from the formation.

[0007] Typically, downhole parameters such as pressure and temperature are obtained and recorded during such treatment processes with one or more downhole sensors. The information obtained by the sensors is later downloaded into surface or remote computers once the treatment operation is complete and the sensors have been tripped out of the wellbore. It has been found, however, that the quality of the treatment operation is evaluated only after such downhole sensors are brought to the surface. As such, the information obtained by the sensors is not supplied in a manner timely enough to allow modifications to the treatment operation. Accordingly, a need has arisen for a communication system for transmitting data between downhole equipment and surface equipment that is operable to provide real-time information relating to parameters and conditions downhole such that modifications to a treatment operation may occur, if desired.

SUMMARY OF THE INVENTION

[0008] The present invention disclosed herein provides a communication system for transmitting data between downhole equipment and surface equipment. The system of the present invention is operable to provide real-time information relating to parameters and conditions downhole such that modifications to a treatment operation may occur, if desired.

[0009] In one aspect, the present invention is directed to a downhole telemetry system that is disposed within a wellbore. The downhole telemetry system includes a downhole transmitter operable to optically transmit a data stream and a downhole receiver operable to receive the optically transmitted data stream. An optically transmissive fluid is disposed in the wellbore and provides a medium for the optical transmission of the data stream between the downhole transmitter and the downhole receiver.

[0010] In one embodiment, a tubular string supports the downhole transmitter and the downhole receiver. In this embodiment, the optically transmissive fluid may be disposed in an annulus between the tubular string and the wellbore, in an interior of the tubular string or both. In some embodiments, the downhole transmitter may be positioned uphole of a downhole receiver, downhole of a downhole receiver or both to enable communication of surface commands downhole, downhole data uphole or both. In certain embodiments, the optical transmission of the data stream may be accomplished using a light beam such as a laser. The optically transmissive fluid may be a brine and may include suspended solids.

[0011] In another aspect, the present invention is directed to a method for transmitting data within a wellbore. The method includes disposing an optically transmissive fluid within the wellbore to provide a medium for optical transmission of data and optically transmitting a data stream through the optically transmissive fluid between a downhole transmitter and a downhole receiver.

[0012] The method may also include disposing suspending particles in the optically transmissive fluid, transmitting light through the optically transmissive fluid or transmitting laser through the optically transmissive fluid.

[0013] In a further aspect, the present invention is directed to a downhole telemetry system disposed within a wellbore. The downhole telemetry system includes a downhole transmitter operable to optically transmit a data stream, a downhole repeater operable to receive the optically transmitted data stream from the downhole transmitter and to optically retransmit the data stream and a downhole receiver operable to receive the optically retransmitted data stream. An optically transmissive fluid is disposed in the wellbore and provides a medium for the optical transmission of the data stream between the downhole transmitter and the downhole repeater and for the optical retransmission of the data stream between the downhole repeater and the downhole receiver.

[0014] In one embodiment, a tubular string supports the downhole transmitter, the downhole repeater and the downhole receiver. In this embodiment, the optically transmissive fluid may be disposed in an annulus between the tubular string and the wellbore, an interior of the tubular string or both. In certain embodiments, a plurality of downhole repeaters may be disposed within the wellbore between the original downhole transmitter and the final downhole receiver. In this embodiment, each of the downhole repeaters is operable to receive the optically transmitted data stream and to optically retransmit the data stream such that the data stream may be sent over a long distance.

[0015] In yet another aspect, the present invention is directed to a downhole telemetry system disposed within a wellbore. The downhole telemetry system includes a first downhole transmitter operable to transmit a data stream via a first transmission mode, a first downhole receiver operable to receive the data stream transmitted via the first transmission mode, a second downhole transmitter communicably associated with the first downhole receiver and operable to retransmit the data stream via a second transmission mode and a second downhole receiver operable to receive the data stream retransmitted via the second transmission mode. In this system, one of the first and the second transmission modes is optical transmission and an optically transmissive fluid that is disposed in the wellbore provides a medium for the optical transmission of the data stream.

[0016] In one embodiment, the other of the first and the second transmission modes is selected from acoustic transmission, electromagnetic transmission, electrical transmission and sonar transmission.

[0017] In an additional aspect, the present invention is directed to a method for transmitting data within a wellbore. The method includes transmitting a data stream via a first transmission mode, receiving the data stream transmitted via the first transmission mode, retransmitting the data stream via a second transmission mode and receiving the data stream retransmitted via the second transmission mode, wherein one of the first and the second transmission modes is optical transmission and wherein an optically transmissive fluid disposed in the wellbore provides a medium for the optical transmission of the data stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0019] FIG. **1** is a schematic illustration of a offshore oil and gas platform positioned over a well that traverses a hydrocarbon bearing subterranean formation in which an embodiment of a downhole telemetry system of the present invention is operating;

[0020] FIG. **2** is a cross sectional view taken of a gravel packing apparatus having integrated sensors for operation in the downhole telemetry system of the present invention;

[0021] FIG. **3** is a block diagram of a sensor for operation in the downhole telemetry system of the present invention;

[0022] FIG. **4** is a side view of a flat pack wire bundle for use the downhole telemetry system of the present invention;

[0023] FIG. **5** is a cross sectional view taken along line **5-5** of FIG. **4** of a flat pack wire bundle for use the downhole telemetry system of the present invention;

[0024] FIG. **6** is a schematic illustration of a offshore oil and gas platform positioned over a well that traverses a hydrocarbon bearing subterranean formation in which another embodiment of a downhole telemetry system of the present invention is operating;

[0025] FIG. **7** is a schematic illustration of a offshore oil and gas platform positioned over a well that traverses a hydrocarbon bearing subterranean formation in which another embodiment of a downhole telemetry system of the present invention is operating; and

[0026] FIG. **8** is a schematic illustration of a offshore oil and gas platform positioned over a well that traverses a hydrocarbon bearing subterranean formation in which another embodiment of a downhole telemetry system of the present invention is operating.

DETAILED DESCRIPTION OF THE INVENTION

[0027] While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use the invention, and do not delimit the scope of the invention.

[0028] Referring initially to FIG. **1**, a downhole telemetry system including a series of optical communication components in use in a well is schematically illustrated and generally designated **10**. A semi-submergible platform **12** is centered over a submerged oil and gas formation **14** located below sea floor **16**. A subsea conduit **18** extends from deck **20** of platform **12** to wellhead installation **22** including blowout preventers **24**. Platform **12** has a derrick **26** and a hoisting apparatus **28** for raising and lowering pipe strings including a work string **30**. Work string **30** is positioned within well **32** having casing **34** that has been secured within well **32** by cement **36**. In the illustrated embodiment, work string **30** includes a sump packer **38**, a gravel packing apparatus or sand screen **40** including a plurality of sensors **42** and a crossover assembly **44** including a gravel packer **46**. Work string **30** also includes a plurality of optical communication components **48**, **50**, **52**, **54**, **56** and **58**. A wired communication link **60** that passes through gravel packer **46** provides a communication medium for communication between sensors **42** and optical communication component **48**. Similarly, a wired communication link disposed within pipe segment **62** provides a communication medium for communication between optical communication component **52** and optical communication component **54** across blowout preventers **24**. Optical transmission between various optical communication components is achieved via an optically transmissive fluid medium **64** disposed within annulus **66**, the interior of work string **30** or both.

[0029] A typical completion process using gravel packing apparatus **40** having integrated sensors **42** will now be described. First, the production interval **68** adjacent to formation **14** is isolated. Packer **46** seals the upper end of production interval **68** and packer **38** seals the lower end of production interval **68**. Crossover assembly **44** is located adjacent to gravel packing apparatus **40**, traversing packer **46** with portions of crossover assembly **44** on either side of packer **46**. When the gravel packing operation commences, the objective is to uniformly and completely fill the production interval **68** with gravel. To help achieve this result, a wash pipe is disposed within gravel packing apparatus **40**. The wash pipe extends into crossover assembly **44** such that return fluid passing through gravel packing apparatus **40** may travel through the wash pipe and into annulus **66** for return to the surface.

[0030] The fluid slurry containing gravel is pumped down work string **30** into crossover assembly **44**. The fluid slurry containing gravel exits crossover assembly **44** through a series of crossover ports and is discharged into annular interval **68**, such that the gravel drops out of the slurry and builds up from formation **14**, filling the perforations and annular interval **68** around gravel packing apparatus **40** forming the gravel pack. Some of the carrier fluid in the slurry may leak off through the perforations into formation **14** while the remainder of the carrier fluid passes through gravel packing apparatus **40**, that is sized to prevent gravel from flowing therethrough. The fluid flowing back through gravel packing apparatus **40**, as explained above, flows back to the surface. This process progresses along the entire length of gravel packing apparatus **40** such that annular interval **68** becomes completely packed with the gravel. Once annular interval **68** is completely packed with gravel, the gravel pack operation may cease.

[0031] Throughout the gravel placement process, sensors **42** that are operably associated with gravel packing apparatus **40** and wired communication link **60** are used to monitor the entire gravel packing operation and provide substantially real time data relating to the gravel placement. Sensors **42** are position in a variety of circumferential, axial and radial locations relative to gravel packing apparatus **40**. For example, as seen in FIG. **2**, gravel packing apparatus **40** includes sensors **42** positioned on the outer and inner surfaces of base pipe **70**, the outer and inner surfaces of screen wire **72** and on the outer and inner surfaces of wash pipe **74**. Sensors **42** may be any one or more of the following types of sensors, including pressure sensors, temperature sensors, piezoelectric acoustic sensors, flow meters for determining flow rate, accelerometers, resistivity sensors for determining water content, velocity sensors, weight sensors or any other sensor that measures a fluid property or physical parameter downhole. As used herein, the term sensor shall include any of these sensors as well as any other types of sensors, such as fiber optic distributed temperature sensors, that are used in downhole environments and the equivalents to these sensors.

[0032] As illustrated in FIG. **3**, a sensor **42** can be powered by a battery **80**. In the illustrated embodiment, sensor **42** is coupled to transceiver **82** that is used to transmit data and receive instructions between sensor **42** and the surface or between sensor **42** and another downhole system. Sensor **42** has a microprocessor **84** associated therewith to allow for manipulation and interpretation of the sensor data and for processing the received instructions. Likewise, sensor **42** is coupled to a memory **86** which provides for storing information for later batch processing or batch transmission, if desired. Importantly, this combination of components provides for localized control and operation of an actuator **88** which may be a flow control device, such as a sliding sleeve, associated with gravel packing apparatus **40** to selectively permit and prevent fluid flow therethrough or which may be a safety device or other actuatable downhole device.

[0033] Referring again to FIG. **1**, sensors **42** provide substantially real time data on the effectiveness of the treatment operation. For example, during a gravel packing operation, voids may be identified during the gravel placement process that allow the operator to adjust treatment parameters such as pump rate, gravel concentration, fluid viscosity and the like to overcome deficiencies in the gravel pack. This real time data is then sent to the surface via the downhole telemetry system of the present invention. As a first step, the data collected sensors **42** is encoded into electrical signals utilizing, for example, "1" and "0" for information transmission. The encoded electrical signal is then transmitted to optical communication component **48** via wired communication link **60**.

[0034] Optical communication component **48** operates as a transducer to convert the digitally encoded electrical signal into a digitally encoded optical data stream in the form of light radiation such as a laser. In a preferred embodiment, optical communication component **48** emits coherent light radiation in a narrow, low-divergence monochromatic beam with a well-defined wavelength. Optical communication component **48** includes a transmitter that transmits the optical data stream to optical communication component **50** that includes a receiver. The optical data stream is sent in annulus **66** which contains an optically transmissive fluid medium **64**. Suitable optically transmissive fluids include clear fluids such as water as well as fluids containing various suspended particles such as brines that may includes salts such as sodium chloride, sodium formate, calcium chloride, calcium bromide, zinc chloride, zinc bromide, potassium chloride, potassium bromide, potassium formate, caesium formate and the like. Optically transmissive fluid medium **64** may alternatively or additionally include other suspended particles including engineered particles of glass or polymers preferably having flat surfaces or other desirable refraction surfaces.

[0035] In a highly optically transmissive medium, the digitally encoded optical data stream will tend to travel in the straight path maintaining its narrow beam format. As most wellbores do not provide a straight path, the optically transmissive fluid medium of the present invention uses the suspended particles to scatter the light beam, thus allowing the information carried in the digitally encoded optical data stream to travel between the optical communication components of the present invention. Specifically, scattering allows the digitally encoded optical data stream to deviate from a straight trajectory due to the localized non-uniformities created by the suspended particles in optically transmissive fluid medium **64**. As the suspended particles in optically transmissive fluid medium **64** cause a large number of scattering events of the digitally encoded optical data stream, the path of the digitally encoded optical data stream diffuses to fill the entire annulus **66** with light radiation.

[0036] In the illustrated embodiment, optical communication component **50** is positioned between optical communication component **48** and optical communication component **52** to provide amplification and repeater functionality. Specifically, optical communication component **50** is positioned relative to optical communication component **48** such that the light radiation intensity is sufficient at optical communication component **50** to read the data digitally encoded within the optical data stream. Preferably, optical communication component **50** optically or electrically processes the data stream and retransmits the data stream as another digitally encoded optical data stream to optical communication component **52**.

[0037] Even though FIG. **1** depicts three optical communication components disposed within wellbore **32** below sea floor **16**, those skilled in the art will recognize that the number of optical communication components needed in a given installation will depend on factors including the length of the wellbore, the optical transmissivity of the fluid medium, the concentration of suspended particles, the strength and type of light radiation used and the like. Accordingly, any number of optical communication components, each having a transmitter and a receiver, may serve as repeaters without departing from the principles of the present invention.

[0038] In the illustrated embodiment, optical communication component **52** includes a transducer that converts the digitally encoded optical data stream to an electrical signal such that the data stream may be passed through blowout preventers **24**. Specifically, as blowout preventers **24** create a discontinuity in the optically transmissive fluid medium **64**, another communication mode is used. In this embodiment, a wired communication link disposed within pipe segment **62** provides a communication medium for communication between optical communication component **52** and optical communication component **54** across blowout preventers **24**. Specifically, as best seen in FIGS. **4** and **5**, a flat pack umbilical line **90** may be used to provide the wired communication link. In the illustrated embodiment, umbilical line **90** includes an instrument line **92**, such as a copper wire, a coaxial cable, a fiber optic bundle, a twisted pair or other line suitable for transmitting signals, data and the like, and a hydraulic line **94**. In addition, umbilical line **90** includes a pair of bumper bars **96**, **98** such as braided wire, which provides added rigidity to umbilical line **90**. Alternatively, instead of including hydraulic line **94**, certain embodiments of umbilical line **90** could utilize a pair of instrument lines. Also, instead of being disposed within pipe segment **62**, a wired communication link could alternatively be disposed exteriorly of pipe segment **62** or could be embedded or integrated within pipe segment **62**.

[0039] Continuing on the communication path depicted in FIG. **1**, the encoded electrical signal is transmitted to optical communication component **54** from the wired communication link associated with pipe segment **62**. Optical communication component **54** operates as a transducer to convert the digitally encoded electrical signal into a digitally encoded optical data stream. As illustrated, the optical data stream is transmitted from optical communication component **54** to optical communication component **56** in annulus **100** which contains optically transmissive fluid medium **64**. Optical communication component **56** provides amplification and repeater functionality by optically or electrically processing the data stream and retransmitting the data stream as another digitally encoded optical data stream to optical communication component **58**. Optical communication component **58** preferably includes a transducer that converts the digitally encoded optical data stream to an electrical signal such that the data stream may be passed to a surface computer for further processing and analysis.

[0040] As large amounts of information can be transmitted optically in substantially real time using the present invention, the information may be used to make changes in the treatment process that enhance the quality of the treatment process. As one example, it may desirable to open certain sliding sleeves or valves associated with the wash pipe disposed within gravel packing apparatus **40** such that the return path for fluids is altered. In this case, such a command can be sent to the appropriate sensor **42** that can actuate such a sliding sleeve or valve. The command can be sent using the telemetry system described above as a downlink. Specifically, a digitally encoded electrical command may be sent to optical communication component **58** that converts the digitally encoded electrical command into a digitally encoded optical command which is sent via optically transmissive fluid medium **64** to optical communication component **56** which in turn retransmits the digitally encoded optical command for receipt by optical communication component **54**. The command is then send from optical communication component **54** to optical communication component **52** via the wired communication link disposed within pipe segment **62**. The optical retransmission continues from optical communication component **52** to optical communication component **50** and finally to optical communication component **48** which converts the digitally encoded optical command to a digitally encoded electrical command that is sent to the appropriate sensor **42** via wired communication link **60**. Actuator **88** of sensor **42** then causes the actuation of the desired sliding sleeve or valve. In using the telemetry system of the present invention as a downlink, it may be desirable to use a beam of coherent light radiation in a narrow, low-divergence monochromatic beam with a different well-defined wavelength than that used for data communication in the uphole direction. Likewise, multiple beams of coherent light radiation in a narrow, low-divergence monochromatic beam with different well-defined wavelengths can be used simultaneously to provide multiple channels of communication in either the uphole direction, the downhole direction or both.

[0041] The telemetry system of the present invention may also be used to enhance a frac pack operation. In certain frac pack completions, it is desirable to perform a mini frac prior to performing the full fracture stimulation and gravel packing treatment. Typically, the mini frac is performed using a relative small volume of frac fluid to test the formation response to the proposed treatment regime. In such a treatment scenario, the frac fluid is pumped down work string **30**, through crossover assembly **44** into annular interval **68**, through the perforations and into formation **14** without taking return fluids. During this process, sensors **42** are used to monitor various aspects of the mini frac, such as temperature and pressure at various locations and particularly temperature during the bleed-off period. As the mini frac is relatively short in duration, the data obtained during the mini frac is preferably stored by sensors **42** until the mini frac is complete. At this point, it may be desirable to circulate an optically transmissive fluid into the well through which the digitally encoded optical data stream generated by the optical communication components may be transmitted. Following the communication path described above, the data obtained by sensors **42** may be sent to the surface via optical communication components **48**, **50**, **52**, **54**, **56**, **58** and the wired communication link associated with pipe segment **62**. This substantially real time information can then be used to alter or refine the planned frac pack treatment operation.

[0042] Even though FIG. **1** depicts a vertical well, it should be noted by one skilled in the art that the telemetry system of the present invention are equally well-suited for use in wells having other directional orientations such as deviated wells, inclined wells or horizontal wells. Accordingly, it should be apparent to those skilled in the art that the use of directional terms such as above, below, upper, lower, upward, downward and the like are used in relation to the illustrative embodiments as they are depicted in the figures, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure. Also, even though FIG. **1** depicts an offshore operation, it should be noted by one skilled in the art that the telemetry system of the present invention are equally well-suited for use in onshore operations or other dry tree installations.

[0043] As described above with reference to the wired communication link disposed within pipe segment **62**, the optical communication components of the present invention can be integrated into a telemetry system the utilizes one or more other data transmission modes. As best seen in FIG. **6**, a plurality of optical communication components **48**, **50**, **52** provide bidirectional optical communications via optically transmissive fluid medium **64** disposed within annulus **66** in the portion of the well below sea floor **16**. As noted above, as blowout preventers **24** create a discontinuity in the optically transmissive fluid medium **64**, use of another data transmission modes therethrough is desirable. As with the embodiment of FIG. **1**, a wired communication link disposed within pipe segment **62** enables data transmission through blowout preventers **24**. In this embodiment, however, the entire pipe string **102** from blowout preventers **24** to platform **12** supports a wired communication link. Use of this embodiment provides for a more a economical telemetry system as compared to an entirely wired system by using optical communications in the wellbore below the sea floor while only using the wired system above the sea floor.

[0044] Referring next to FIG. **7**, therein is depicted another embodiment of a downhole telemetry system of the present invention that integrates optical communication components with other communication components that use different data transmission modes. In the illustrated embodiment, a plurality of optical communication components **54**, **56**, **58** provide bidirectional optical communications via optically transmissive fluid medium **64** disposed within annulus **66** in the portion of the well above sea floor **16**. Below sea floor **16**, the illustrated telemetry system utilizes a plurality of acoustic communication components **104**, **106**, **108**. For example, acoustic communication components **104**, **106**, **108** may be electromechanical transducers which produce mechanical motion or force in response to a driving electrical signal and respond to mechanical force or motion applied to their mechanical connection by generating an electric field which produces a voltage on its electrical connection, such as a stack of piezoelectric disks. The piezoelectric disks may be formed from various crystalline materials, such as quartz, ceramic materials, PZT (lead-zirconate-titanate), ferroelectric, relaxor ferroelectric, electrostrictor, PMN and the like.

[0045] Upon electrical excitation, these transducers generate vibrations, i.e. acoustic waves, the work string **30** which provide a means of telemetering information. Specifically, after sensors **42** collect data, this data is encoded into an electrical waveform which drives the electromechanical transducer of acoustic communication component **104** which generates acoustic waves in work string **30** which travel up work string **30** and are received by acoustic communication component **106** this serves as an intermediate repeater. Acoustic communication component **106** retransmits the data by again generating acoustic waves in work string **30** which travel up work string **30** and are received by acoustic communication component **108**. The received acoustic signals are converted back to electrical signals by each of the receiving transducer and decoded to recover the data obtained by sensors **42**.

[0046] Acoustic communication component **108** feeds a digitally encoded electrical signal to the wired communication link disposed within pipe segment **62** which forwards the data carried in the electrical signal to optical communication component **54** for transmission to the surface via optical communication components **56**, **58** and optically transmissive fluid medium **64** as described above. In this manner, an acoustic telemetry system can be used for data transmission downhole with the aid of the optical transmission mode of the present invention to overcome the problems associates with acoustic transmissions in the noisy environment provided in subsea conduit **18**.

[0047] Referring next to FIG. **8**, therein is depicted another embodiment of a downhole telemetry system of the present invention that integrates optical communication components with other communication components using multiple data transmission modes. A plurality of optical communication components **48**, **50** provide bidirectional optical communications via optically transmissive fluid medium **64** disposed within annulus **66** in the portion of the well below sea floor **16**. In addition, communication component **110** not only has optical communication capabilities, but is also operable to retransmit a digital data stream via electromagnetic waves. Specifically, communication component **110** has a transducer for converting the digitally encoded optical data stream into an electrical signal that is processed to establish the frequency, power and phase output that is fed to an electromagnetic transmitter

[0048] The electromagnetic transmitter may be a direct connect type transmitter that utilizes an output voltage applied between two electrical terminals that are electrically isolated from one another to generate electromagnetic waves **112** that are radiated into the earth carrying the information obtained by sensors **42**. Alternatively, the transmitter may include a magnetically permeable annular core, a plurality of primary electrical conductor windings and a plurality of secondary electrical conductor windings which are wrapped around the annular core. Collectively, the annular core, the primary windings and the secondary windings serve to approximate an electrical transformer which generates electromagnetic waves **112**.

[0049] Electromagnetic waves **112** travel through the earth and are received by subsea repeater **114** located on sea floor **16**. Subsea repeater **114** may detect either the electrical field (E-field) component of electromagnetic waves **112**, the magnetic field (H-field) component of electromagnetic waves **112** or both. As electromagnetic waves **112** reach subsea repeater **114**, a current is induced in subsea repeater **114** that carries the information originally obtained by sensors **42**. The current is fed to an electronics package within subsea repeater **114** for processing.

[0050] After the electrical signal has been processed, it is forwarded to an sonar modem **116** that will transform the electrical signal into sound waves **118**. The information may be encoded into sound waves **118** by sonar modem **116** using, for example, frequency shift keying (FSK) or multiple frequency shift keying (MFSK). Sound waves **118** are transmitted through the sea carrying the information originally obtained by sensors **42**. Sound waves **118** are then picked up by sonar modem **120** and forwarded to the surface via electric wire **122**. As with each of the above described telemetry systems, the telemetry system described with reference to FIG. **8** may also be used as a downlink to communicate information from the surface to a downhole device.

[0051] While this invention has been described with a reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments as well as other embodiments of the invention, will be apparent to persons skilled in the art upon reference to the description. It is, therefore, intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A downhole telemetry system disposed within a wellbore, the downhole telemetry system comprising:
- a downhole transmitter operable to optically transmit a data stream;
- a downhole receiver operable to receive the optically transmitted data stream; and
- an optically transmissive fluid disposed in the wellbore that provides a medium for the optical transmission of the data stream between the downhole transmitter and the downhole receiver.

2. The downhole telemetry system as recited in claim **1** further comprising a tubular string that supports the downhole transmitter and the downhole receiver.

3. The downhole telemetry system as recited in claim **2** wherein the optically transmissive fluid is disposed in at least one of an annulus between the tubular string and the wellbore and an interior of the tubular string.

4. The downhole telemetry system as recited in claim **1** wherein the downhole transmitter is positioned uphole of the downhole receiver.

5. The downhole telemetry system as recited in claim **1** wherein the downhole transmitter is positioned downhole of the downhole receiver.

6. The downhole telemetry system as recited in claim **1** wherein the data stream further comprises at least one of surface commands and downhole data.

7. The downhole telemetry system as recited in claim **1** wherein the optically transmitted data stream further comprises at least one of light and laser.

8. The downhole telemetry system as recited in claim **1** wherein the optically transmissive fluid further comprises a brine.

9. The downhole telemetry system as recited in claim **1** wherein the optically transmissive fluid further comprises suspended solids.

10. A method for transmitting data with a wellbore, the method comprising:
- disposing an optically transmissive fluid within the wellbore to provide a medium for optical transmission of data; and
- optically transmitting a data stream through the optically transmissive fluid.

11. The method as recited in claim **10** further comprising suspending particles in the optically transmissive fluid.

12. The method as recited in claim **10** wherein optically transmitting a data stream through the optically transmissive fluid further comprises transmitting light through the optically transmissive fluid.

13. The method as recited in claim **10** wherein optically transmitting a data stream through the optically transmissive fluid further comprises transmitting laser through the optically transmissive fluid.

14. A downhole telemetry system disposed within a wellbore, the downhole telemetry system comprising:
- a downhole transmitter operable to optically transmit a data stream;
- a downhole repeater operable to receive the optically transmitted data stream from the downhole transmitter and to optically retransmit the data stream;
- a downhole receiver operable to receive the optically retransmitted data stream; and
- an optically transmissive fluid disposed in the wellbore that provides a medium for the optical transmission of the data stream between the downhole transmitter and the downhole repeater and for the optical retransmission of the data stream between the downhole repeater and the downhole receiver.

15. The downhole telemetry system as recited in claim **14** wherein the optically transmissive fluid further comprises a brine.

16. The downhole telemetry system as recited in claim **14** wherein the optically transmissive fluid further comprises suspended solids.

17. The downhole telemetry system as recited in claim **14** further comprising a tubular string that supports the downhole transmitter, the downhole repeater and the downhole receiver and wherein the optically transmissive fluid is disposed in at least one of an annulus between the tubular string and the wellbore and an interior of the tubular string.

18. The downhole telemetry system as recited in claim **14** further comprising a plurality of downhole repeaters disposed with the wellbore between the downhole transmitter and the downhole receiver, each of the downhole repeaters operable to receive the optically transmitted data stream and to optically retransmit the data stream.

19. A downhole telemetry system disposed within a wellbore, the downhole telemetry system comprising:
- a first downhole transmitter operable to transmit a data stream via a first transmission mode;
- a first downhole receiver operable to receive the data stream transmitted via the first transmission mode;
- a second downhole transmitter communicably associated with the first downhole receiver operable to retransmit the data stream via a second transmission mode; and
- a second downhole receiver operable to receive the data stream retransmitted via the second transmission mode;
- wherein one of the first and the second transmission modes is optical transmission; and
- wherein an optically transmissive fluid disposed in the wellbore provides a medium for the optical transmission of the data stream.

20. The downhole telemetry system as recited in claim **19** wherein the other of the first and the second transmission modes is selected from acoustic transmission, electromagnetic transmission, electrical transmission and sonar transmission.

21. The downhole telemetry system as recited in claim **19** further comprising a tubular string that supports the first and second downhole transmitters and the first and second downhole receivers and wherein the optically transmissive fluid is disposed in at least one of an annulus between the tubular string and the wellbore and an interior of the tubular string.

22. The downhole telemetry system as recited in claim **19** wherein the optically transmissive fluid further comprises a brine.

23. The downhole telemetry system as recited in claim **19** wherein the optically transmissive fluid further comprises suspended solids.

24. A method for transmitting data with a wellbore, the method comprising:

transmitting a data stream via a first transmission mode;

receiving the data stream transmitted via the first transmission mode;

retransmitting the data stream via a second transmission mode; and

receiving the data stream retransmitted via the second transmission mode;

wherein one of the first and the second transmission modes is optical transmission; and

wherein an optically transmissive fluid disposed in the wellbore provides a medium for the optical transmission of the data stream.

25. The method as recited in claim **24** wherein the other of the first and the second transmission modes is selected from acoustic transmission, electromagnetic transmission, electrical transmission and sonar transmission.

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