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(54) **Packer set monitoring and control**

(57) The compression of a packer (16) in a well is monitored by using a sensor (30) in the well, the sensor

providing an output signal to an apparatus (32) responsive thereto to change the compression in the packer to a predetermined value.

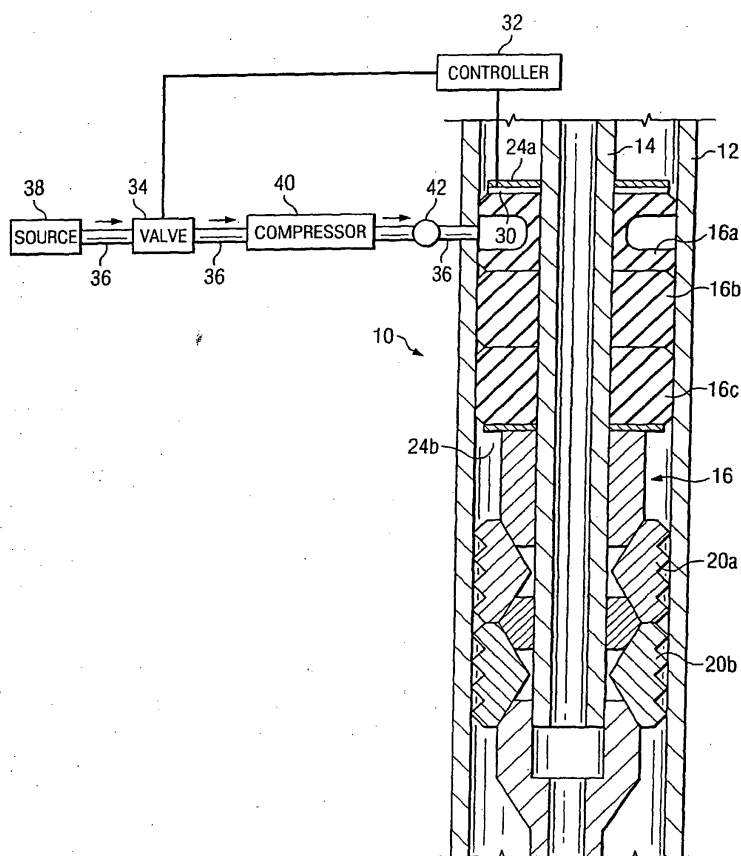


Fig. 2

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Description

[0001] This invention relates to a method and apparatus for monitoring and controlling the compression of a packer in a well.

[0002] Downhole packers are commonly used in many oilfield applications for the purpose of sealing against the flow of fluid to isolate one or more portions of a wellbore for the purposes of testing, treating, or producing the well. The packers are suspended from a tubing string, or the like, in the wellbore, or in a casing in the wellbore, and extend between the inner surface of the wellbore, or casing and the outer surface of the carrier tubing. Each packer includes one or more elastomer elements which are activated, or set, so that the packer elements are forced against the inner surface of the wellbore, or casing, and the outer surface of the carrier tubing, and compressed to seal against the flow of fluid and therefore to permit isolation of certain zones in the well.

[0003] Under normal circumstances the packer elements retain their compression, or set, for a significant duration. However, packers often suffer from "set loss" in which they lose their compression for a number of reasons including, for example, an improper setting, material creep, and the like. This compromises the integrity of the seal and can lead to downhole leakage, requiring a workover operation which is expensive and time-consuming.

[0004] Some prior art techniques have addressed this problem by determining in a laboratory the amount of compression required to correctly set a given packer design, under the assumption that similar conditions are present downhole. However, in many instances the packer setting process (loading rate, for example) and conditions (such as the presence of fluids, debris, and the condition of the tubing/casing inner diameter and the surface) cannot be replicated in the laboratory. As a result, the actual setting behavior of the packer may be different from that experienced in the laboratory and the problem is not solved.

[0005] We have now devised a system and method to meet this requirement.

[0006] In one aspect, the present invention provides a system for controlling the compression of a packer disposed in a well, comprising a sensor disposed in the well for sensing the compression of the packer and generating a corresponding output signal; and an apparatus responsive to the output signal for changing the compression of the packer in response to the sensed compression deviating from a predetermined value.

[0007] In another aspect, the present invention provides a method of controlling the compression of a packer disposed in a well, comprising the steps of sensing the compression of the packer; generating a corresponding output signal; and changing the compression of the packer in response to the sensed compression deviating from a predetermined value.

[0008] In the systems of the invention, preferably the sensor is arranged to sense any decrease in the compression of the packer below a predetermined value, and in response the apparatus is arranged to increase the compression of the packer to raise it back to the predetermined value. The systems preferably comprise a controller for receiving the output signal from the sensor, processing the signal, and providing an output signal corresponding to the compression of the packer, wherein the apparatus is responsive to the output signal provided by the controller. Examples of sensors are strain gauges and pressure sensors. The sensors can, for example, be located on, or embedded in, the packer.

[0009] A preferred packer comprises a packer element, and a shoe engaging the packer element; and the sensor can be mounted on the packer element located between the packer element and the shoe.

[0010] In another arrangement, the sensor comprises a hydraulic cylinder; and a piston moveable in the hydraulic cylinder in response to the deviation in compression of the packer. The sensor may further comprise a rod extending from the piston and engaging the packer so that changes in the compression of the packer causes movement of the rod and therefore the piston. Thus, movement of the piston can cause changes in fluid pressure in the hydraulic cylinder, and the sensor may further comprise a fluid pressure sensor responsive to the pressure in the hydraulic cylinder for generating the output signal. The apparatus may comprise a source of fluid; and a pump responsive to the output signal for controlling the flow of fluid to the hydraulic cylinder to control the movement of the piston and therefore the compression of the packer. Preferably, a motor is provided for driving the pump, wherein the motor is responsive to the output signal for driving the pump.

[0011] In the method of the invention, the step of changing preferably comprises the step of increasing the compression of the packer to raise it back to the predetermined value. In one arrangement, the method further comprises receiving the output signal from the sensor; processing the output signal from the sensor; and providing a processed output signal corresponding to the compression of the packer; wherein the step of changing is in response to the proposed output signal.

[0012] The step of sensing preferably comprises sensing the compressive strain on the packer, or of sensing the pressure on the packer. The step of sensing may be effected by a sensor mounted on, or embedded in, the packer.

[0013] The method may also include the step of forming a cavity in the packer for receiving fluid, wherein the step of changing comprises the step of controlling the flow of fluid to the cavity for increasing the pressure of the packer. The step of changing may further comprise the step of compressing the fluid before it flows to the cavity.

[0014] In the method, the step of sensing may comprise the step of providing a piston moveable in a hy-

hydraulic cylinder in response to the deviation in compression of the packer. Preferably, movement of the piston causes changes in fluid pressure in the hydraulic cylinder, and the step of sensing further comprises the step of sensing the fluid pressure in the hydraulic cylinder. The step of changing may comprise the step of pumping fluid into the hydraulic cylinder to control the movement of the piston and therefore the compression of the packer.

[0015] The invention also provides a system for controlling the compression of a packer disposed in a well, comprising: means disposed in the well for sensing the compression of the packer and generating a corresponding output signal; and means responsive to the output signal for changing the compression of the packer in response to the sensed compression deviating from a predetermined value.

[0016] In order that the invention may be more fully understood, reference will be made to the accompanying drawings, wherein Fig. 1 is a sectional view of a packer utilized in an embodiment of the invention.

[0017] Figs. 2 and 3 are diagrammatic views of examples of a monitoring and compensating system for the packer of Fig. 1.

[0018] Referring to Fig. 1, a downhole tool is referred to, in general, by the reference numeral 10 and is shown installed in a casing 12. It is understood that the casing 12 is disposed in a well and that the tool 10 is lowered to a predetermined depth in the casing 12 as part of a workstring, or the like, (not shown) which often includes other tools used to perform various oil recovery and completion operations.

[0019] The tool 10 includes a tubular member 14 connected as part of the workstring and a packer 16 surrounds a portion of the outer surface of the tool 10 and consists of a series (in the example shown, three) of axially-spaced, annular packer elements 16a, 16b, and 16c. The packer elements 16a, 16b, and 16c can be fabricated, at least in part, from an elastomeric material so that they can be compressed, in a manner to be described.

[0020] The packer 16 also includes a series (in the example shown, two) of annular, axially-spaced anchoring slips 20a and 20b that are also disposed on the outer surface of the tubular member 14 downstream and slightly spaced from the packer elements 16a, 16b, and 16c. The anchoring slips 20a and 20b can be fabricated from a relatively hard material which is adapted to engage the inner wall of the casing 12, as will be described.

[0021] Two annular backup shoes 24a and 24b are disposed at the upper end of the upper packer element 16a and the lower end of the lower packer element 16c, respectively, as viewed in Fig. 1. The backup shoes 24a and 24b, when installed, compress the packer elements 16a, 16b, and 16c during the packer setting process.

[0022] Since the packer elements 16a, 16b, and 16c; the anchoring slips 20a and 20b; and the backup shoes 24a and 24b all are conventional and are connected to

the tubular member 14 in a conventional manner they will not be described in further detail.

[0023] Fig. 2 depicts the packer 16 connected to a monitoring and compensating system, including a sensor 30 mounted between the upper backup shoe 24a and the corresponding end of the packer element 16a to measure, or sense, the amount of compressive stress on the packer element 16a. The sensor 30 can be in the form of a strain gage, for example, in which case it could be mounted on the backup shoe 24a; or it could be in the form of a pressure sensor, for example, in which case it could be mounted on the corresponding end of the packer element 16a. Thus, if there is a change in the packer set, i.e., a change in the amount of compressive stress on the packer elements 16a, 16b, and 16c, which normally would be a reduction in the stress, this change is detected by the sensor 30 which outputs a corresponding electrical signal, in a conventional manner.

[0024] The sensor 30 is connected in an electrical circuit including a controller 32 and a solenoid operated valve 34 connected in series by conventional electrical conductors in a conventional manner. The controller 32 can be a classical PID controller or an adaptive controller and, as such, receives the above output signal from the sensor 30 and compares the signal with a desired threshold value or a "set-point" which corresponds to a reduction in the compression of the packer element 16a from its original set, or a predetermined reduction from its original set. If the signal falls below the set-point, the controller 32 generates an output signal which is passed to the valve 34. The valve 34 is normally closed but is adapted to open when it receives the above signal from the controller 32.

[0025] The valve 34 is part of an apparatus which increases the compression of the packer 16 and which also includes a conduit system 36 through which fluid from a source 38 flows. The valve 34 is connected in the conduit system 36 and controls the flow of the fluid through the conduit system 36, and a fluid compressor 40 is also connected in the conduit system 36 downstream of the valve 34. The compressor 40 can be of any conventional design such as, for example, a piston mounted for reciprocal movement in a cylinder to compress the fluid. The compressor 40 is adapted to receive the fluid from the source 38 and increase the pressure of the fluid, and can be activated automatically upon receipt of the fluid, or it can be activated by the controller 32 in a conventional manner.

[0026] A cavity is formed in the packer element 16a and is connected to the compressor 40 by the conduit system 36. Thus, pressurized fluid flows from the compressor 40 to the cavity in the packer element 16a to increase its compression, or set, and thus compensate for the reduction in the compression sensed by the sensor 30. The flow can continue in this manner until the set of the packer 16 is re-established. A check valve 42 is provided in the conduit system 36 for preventing the flow of fluid from the packer element 16a back to the

compressor 40.

[0027] In operation, the packer 16 is located at a predetermined location in the casing 12 and is set, or activated, in a conventional manner. This causes the packer elements 16a, 16b, and 16c to be forced against the inner wall of the casing 12 as well as the outer wall of the tubular member 14 in compression and, along with the anchoring slips 20a and 20b, to engage the inner surface of the casing 12. A seal is thus formed against the flow of fluids in the annular space between the outer surface of the tubular member 14 and the inner wall of the casing 12 which isolates the corresponding zone in the well.

[0028] The sensor 30 continuously monitors the compressive stress on the packer element 16a and outputs a corresponding signal. If the output signal falls below the set-point value described above, the controller 32 generates a corresponding output signal which is passed to the valve 34 and causes the valve to open and fluid to flow through the conduit system 36, as indicated by the flow arrows. The pressure of the flowing fluid is increased by the compressor 40, and the pressurized fluid is passed to the cavity in the packer element 16a to increase its compression and re-establish its set. When the compressive stress on the packer element 16a returns to normal, as sensed by the sensor 30, the controller 32 responds to a corresponding signal from the sensor 30 and closes the valve 34.

[0029] Although not shown in the drawings for the convenience of presentation, it is understood that the sensor 30 can be embedded in the packer element 16a; mounted on, or embedded in, the packer elements 16b and 16c; or mounted on either backup shoe 24a or 24b. In the event multiple sensors 30 are provided in accordance with the foregoing they could be connected in the above electrical circuit, including the controller 32, or connected in separate, identical, electrical circuits. In either case, the electrical circuit, including the sensor 30, the controller 32, the valve 34, and the associated electrical conductors can also be either mounted on, or embedded in, the packer element 16a or mounted on either backup shoe 24a or 24b. Thus, the operation described above in connection with the packer element 16a is equally applicable to the packer elements 16b and 16c.

[0030] An alternate embodiment of the monitoring system is shown in Fig. 3 in connection with the tool 10 of the embodiment of Fig. 2. According to the embodiment of Fig. 3, an actuator 50 is provided which includes a piston 52 mounted for reciprocal movement in a cylinder 54 in a conventional manner. One end of an actuator rod 56 is connected to an end of the piston 52 and extends through the housing of the cylinder 54. The other end of the actuator rod 56 is connected to the backup shoe 24a of the tool 10.

[0031] A fluid line 58 connects a fluid source 60 to the inlet of a hydraulic pump 62. A fluid line 64 extends from the outlet of the pump 62 into the chamber of the cylinder 54 defined, in part, by the piston 52; and a check valve

66 is disposed in the line 64 to prevent fluid flow from the chamber to the pump 62.

[0032] An electrical motor 68 is operatively connected to the pump 62 for driving it to pump fluid from the source 60, via the line 58, through the pump 62, and, through the line 64 to the chamber of the cylinder 54, as indicated by the flow arrows.

[0033] An electrical circuit is provided which includes a sensing unit 70 connected to the line 64, and a controller 72 electrically connected in series between the sensing unit 70 and the motor 68. The sensing unit 70 senses pressure in the line 64 in a conventional manner and outputs a corresponding signal to the controller 72. The controller 72 is identical to the controller 32 of the previous embodiment and, as such, is adapted to control the operation of the motor 68 in response to the signals received from the sensing unit 70 in a manner to be described.

[0034] In operation of the embodiment of Fig. 3, the packer 16 is located at a predetermined location in the casing 12 and is set, or activated, in a conventional manner. This causes the packer elements 16a, 16b, and 16c to be forced against the inner wall of the casing 12 as well as the outer wall of the tubular member 14 in compression. The backup shoe 24a is forced against the packer element 16a, and the anchoring slips 20a and 20b are forced against the inner wall of the casing 12. A seal is thus formed to prevent the flow of fluids in the annular space between the outer surface of the tubular member 14 and the inner wall of the casing 12 which isolates a corresponding zone in the well.

[0035] The motor 68, and therefore the pump 62, are normally inactive, and the sensing unit 70 continuously monitors the fluid pressure in the chamber of the cylinder 54, via the fluid line 64, and outputs a corresponding signal. If the compression of the packer element 16a is reduced from its original set, the actuator rod 56, and therefore the piston 52, move downwardly, as viewed in Fig. 3. This, in effect, enlarges the chamber in the cylinder 54 and causes an attendant reduction in the fluid pressure in the chamber and in the line 64. This reduced pressure is sensed by the sensing unit 70 and a corresponding signal is outputted from the sensing unit 70 to the controller 72. The controller 72 compares the signal received from the sensing unit 70 with a desired threshold value, or "set-point", of the fluid pressure in the chamber, which corresponds to a reduction in the compression of the packer element 16a from its original set, or a predetermined reduction from its original set. If the signal received from the sensing unit 70 falls below the set-point, the controller 72 generates an output signal which is passed to the motor 68 to activate the motor 68 and drive the pump 62. Fluid is thus pumped from the source 60, through the lines 58 and 64 and the pump 62 and to the chamber of the cylinder 54 to increase the pressure in the chamber and cause the piston 52, and therefore the actuator rod 56, to move in a downwardly direction, as viewed in Fig. 3. This, in turn, forces the

backup shoe 24a further against the packer element 16a to increase its compression and re-establish its set. When this is achieved, the fluid pressure in the line 64 is increased to the extent that the sensing unit 70 outputs a corresponding signal to the controller 72 which, in turn, deactivates the motor 68 and therefore the pump 62.

[0036] Thus, according to the embodiments of Figs. 2 and 3, any set loss of the packer 16 exceeding a predetermined value is immediately determined and compensated for to insure that the original set conditions of the packer 16 are maintained.

[0037] It is understood that although components of the system of the embodiments of Figs. 2 and 3 are shown diagrammatically, and therefore out of scale, for the convenience of presentation, they can be located downhole in the casing 12 or the wellbore.

[0038] It is understood that variations may be made in the foregoing without departing from the scope of the invention. For example, the casing 12 can be eliminated and the tool 10 can be inserted directly in the well. Also, the anchoring slips 20a and 20b can extend upstream from the packer elements 16a, 16b, and 16c. Further, the controllers 32 and 72 can respond to increases or decreases in the compression of the packer 16 from a predetermined value, and generate a corresponding output signal. Still further, in the unlikely event that the compression of the packer 16 needs to be decreased, fluid can be withdrawn from the cavity in the packer 16 and from the cylinder 54 as needed. It is also understood that spatial references, such as "downwardly", "downstream", "between", etc., are for the purpose of illustration only and do not limit the specific orientation or location of the components or fluid flow described above.

[0039] The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated.

Claims

1. A system for controlling the compression of a packer disposed in a well, comprising a sensor disposed in the well for sensing the compression of the packer and generating a corresponding output signal; and an apparatus responsive to the output signal for changing the compression of the packer in response to the sensed compression deviating from a predetermined value.

2. A system according to claim 1, wherein the sensor is arranged to sense any decrease in the compression of the packer below a predetermined value, and in response the apparatus is arranged to increase the compression of the packer to raise it back to the predetermined value.

3. A system according to claim 1 or 2, further comprising a controller for receiving the output signal from the sensor, processing the signal, and providing an output signal corresponding to the compression of the packer, wherein the apparatus is responsive to the output signal provided by the controller.

4. A system according to claim 1, 2 or 3, wherein the sensor is a strain gauge, or a pressure sensor.

5. A system according to claim 1, 2, 3 or 4, wherein the sensor is located on, or embedded in, the packer.

6. A system of claim 5, wherein the packer comprises a packer element; and a shoe engaging the packer element; wherein the sensor is mounted on the packer element and is located between the packer element and the shoe.

7. A system according to claim 5, wherein the packer comprises a packer element, and the sensor is embedded in the packer element.

8. A system according to any of claims 1 to 7, wherein the packer has a cavity for receiving fluid, and the apparatus comprises a valve responsive to the output signal for controlling the flow of fluid to the cavity to change the compression of the packer.

9. A system according to claim 8, wherein the apparatus further comprises a compressor for compressing the fluid before it flows to the cavity.

10. A system according to claim 8 or 9, wherein the cavity is formed in a packer element.

11. A system according to claim 8, wherein the output signal is generated in response to the compression of the packer falling below a predetermined value, and the apparatus increases the pressure in the cavity to restore the compression.

12. A system according to claim 1, 2 or 3, wherein the sensor comprises a hydraulic cylinder; and a piston moveable in the hydraulic cylinder in response to the deviation in compression of the packer.

13. A system according to claim 12, wherein the sensor further comprises a rod extending from the piston and engaging the packer so that changes in the

compression of the packer causes movement of the rod and therefore the piston.

14. A system according to claim 13, wherein movement of the piston causes changes in fluid pressure in the hydraulic cylinder, and the sensor further comprises a fluid pressure sensor responsive to the pressure in the hydraulic cylinder for generating the output signal.

15. A system according to claim 13 or 14, wherein the apparatus comprises a source of fluid; and a pump responsive to the output signal for controlling the flow of fluid to the hydraulic cylinder to control the movement of the piston and therefore the compression of the packer.

16. A system according to claim 15, further comprising a motor for driving the pump, wherein the motor is responsive to the output signal for driving the pump.

17. A method of controlling the compression of a packer disposed in a well, comprising the steps of sensing the compression of the packer; generating a corresponding output signal; and changing the compression of the packer in response to the sensed compression deviating from a predetermined value.

18. A method according to claim 17, wherein the step of changing comprises the step of increasing the compression of the packer to raise it back to the predetermined value.

19. A method according to claim 17 or 18, further comprising the steps of receiving the output signal from the sensor; processing the output signal from the sensor; and providing a processed output signal corresponding to the compression of the packer; wherein the step of changing is in response to the processed output signal.

20. A method according to claim 17, 18 or 19, wherein the step of sensing comprises the step of sensing the compressive strain on the packer, or of sensing the pressure on the packer.

21. A method according to any of claims 17 to 20, wherein the step of sensing is effected by a sensor mounted on, or embedded in, the packer.

22. A method according to any of claims 17 to 21, further comprising the step of forming a cavity in the packer for receiving fluid, wherein the step of changing comprises the step of controlling the flow of fluid to the cavity for increasing the pressure of the packer.

23. A method according to claim 22, wherein the step

of changing further comprises the step of compressing the fluid before it flows to the cavity.

24. A method according to any of claims 17 to 21, wherein the step of sensing comprises the step of providing a piston moveable in a hydraulic cylinder in response to the deviation in compression of the packer.

25. A method according to claim 24, wherein movement of the piston causes changes in fluid pressure in the hydraulic cylinder, and the step of sensing further comprises the step of sensing the fluid pressure in the hydraulic cylinder.

26. A method according to claim 24, wherein the step of changing comprises the step of pumping fluid into the hydraulic cylinder to control the movement of the piston and therefore the compression of the packer.

27. A system for controlling the compression of a packer disposed in a well, comprising means disposed in the well for sensing the compression of the packer and generating a corresponding output signal; and means responsive to the output signal for changing the compression of the packer in response to the sensed compression deviating from a predetermined value.

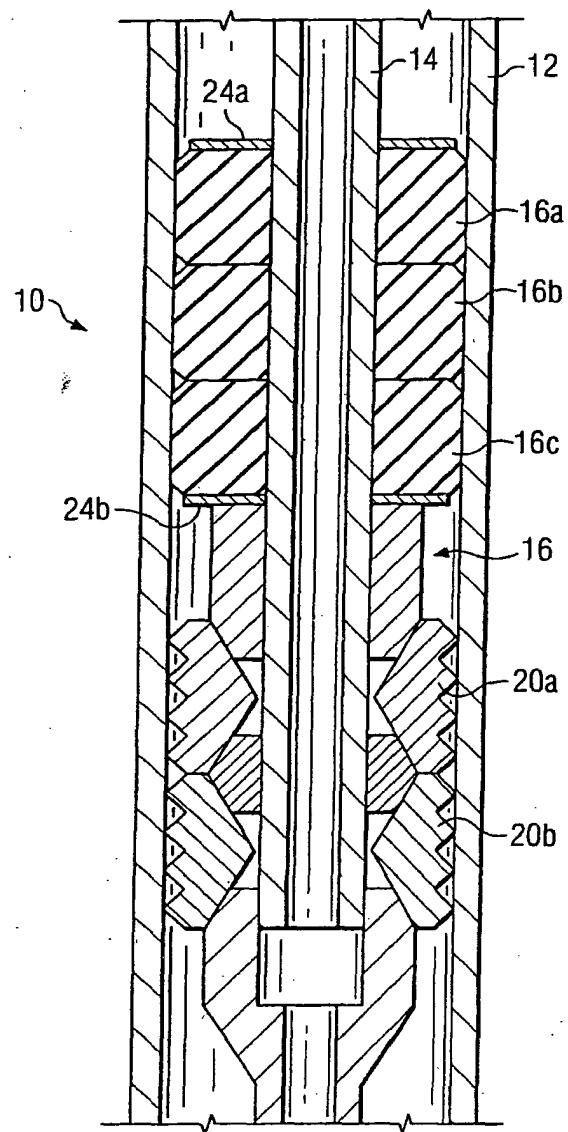


Fig. 1

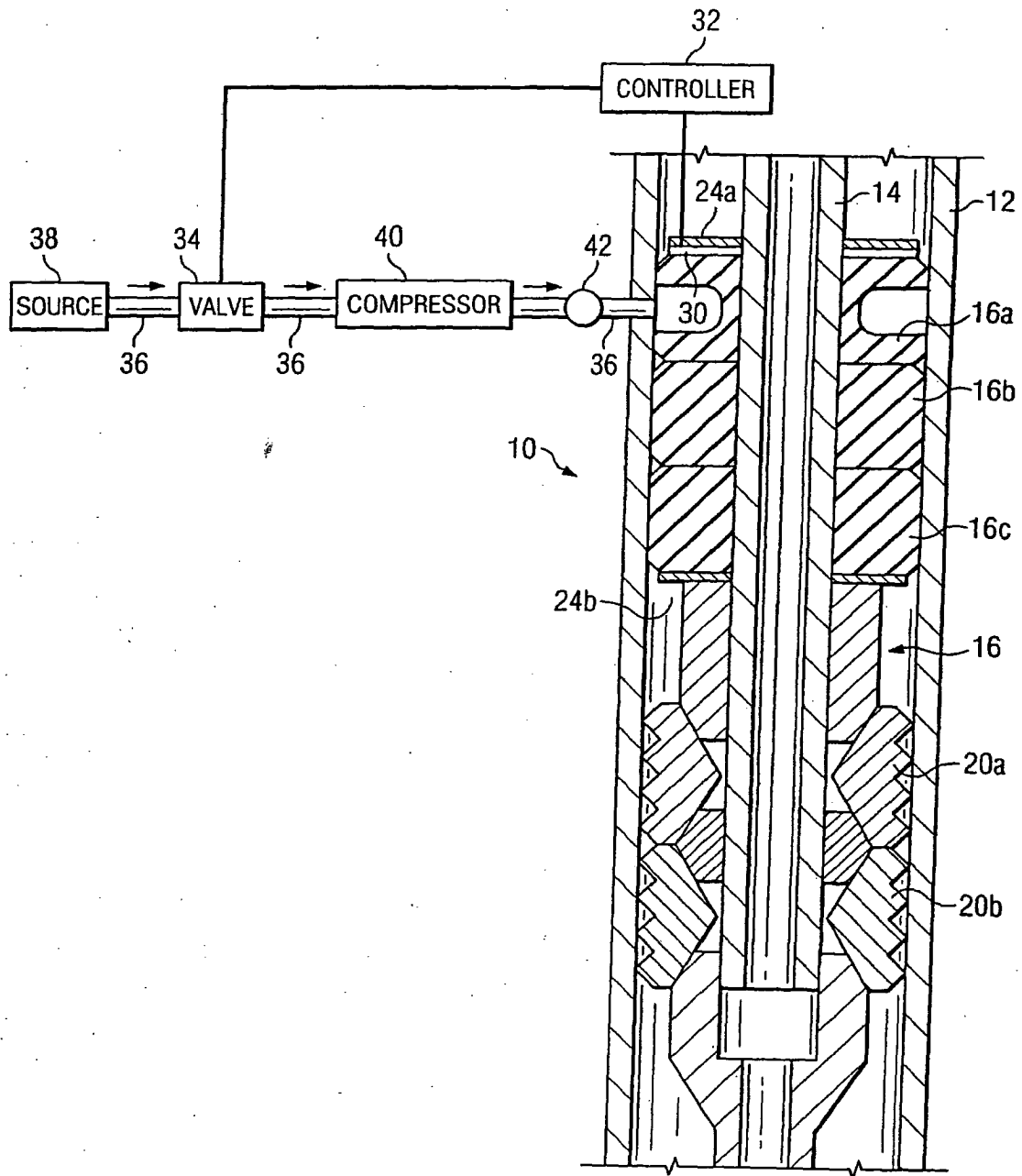


Fig. 2

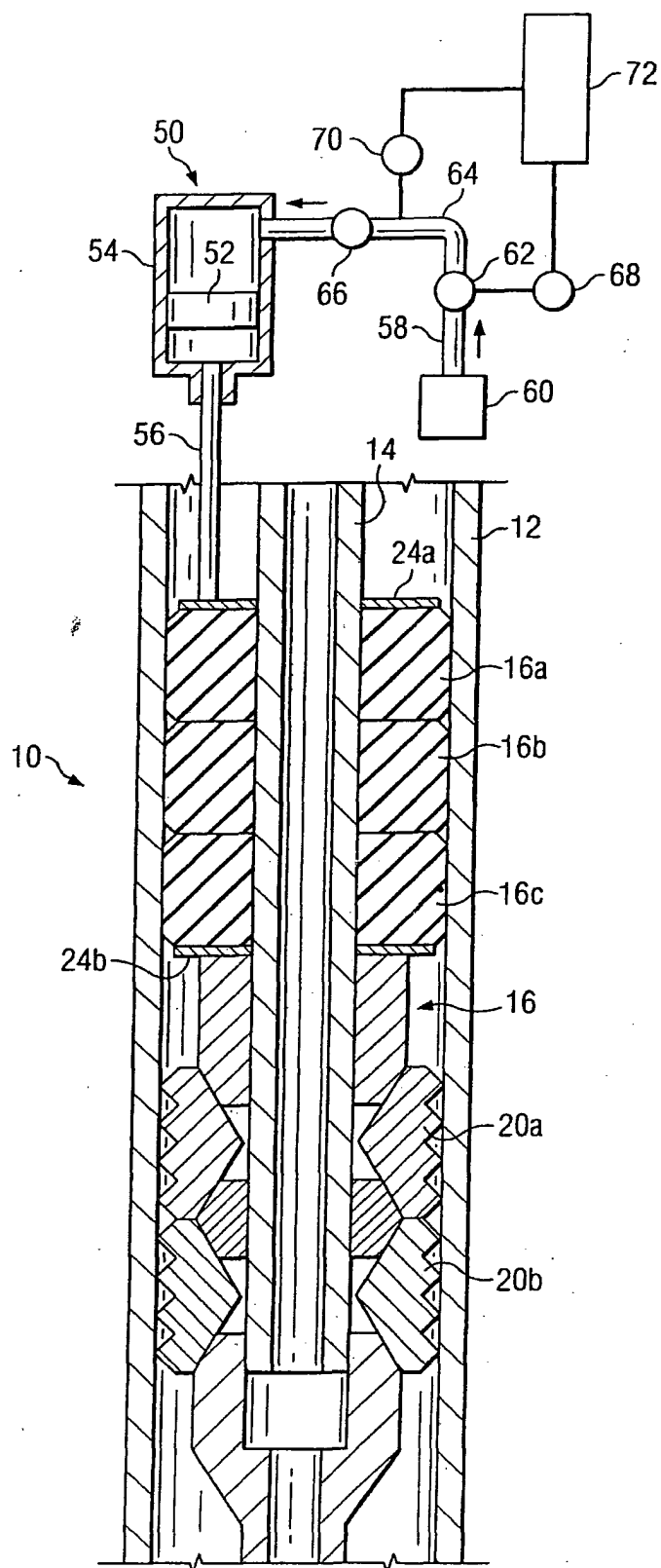


Fig. 3



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EUROPEAN SEARCH REPORT

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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 12 February 2004	Examiner Ott, S
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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The members are as contained in the European Patent Office EDP file on
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