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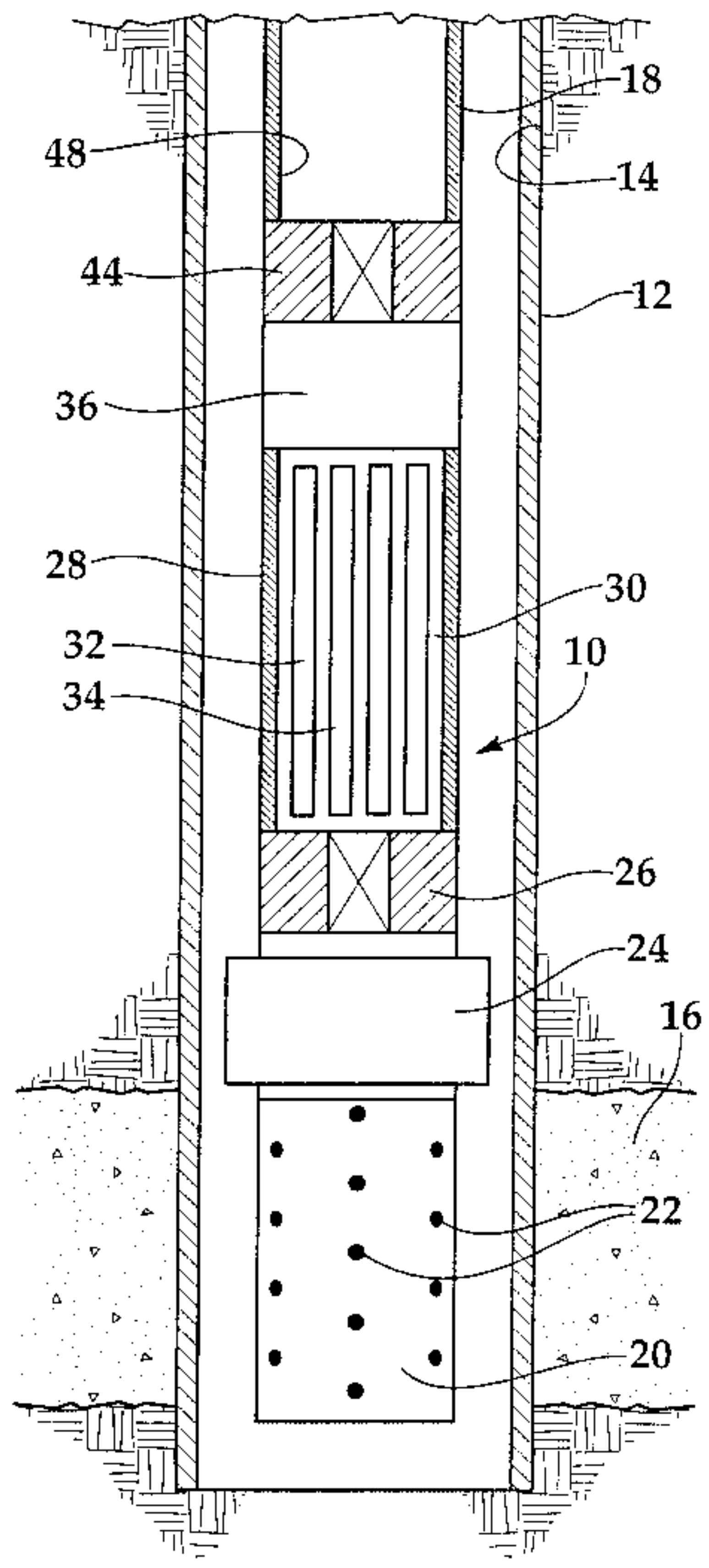
(54) **SYSTEME D'APPRECIATION ANTICIPEE POUR FORAGE TUBE**

(54) **EARLY EVALUATION SYSTEM FOR CASED WELLBORE**



(57) An early evaluation system for use in a cased wellbore (12) is disclosed. The apparatus (10) comprises a tool string (18) with a perforating gun (20) on the lower end thereof. Tool string (18) also including a packer (24), a control valve (26), a sampler (28) and a locating device (36). As the apparatus (10) is run into the wellbore (14), the locating device (36) is used to locate the tool string (18) with respect to the formation (16). A second control valve (44) may be disposed above the sampler (28) so that fluid may be pumped down the tool string (18) and back into the formation (16) when the control valve (44) is opened. In operation, the perforating gun (20) is fired after the packer (24) is set, so that fluid initially flows into the spent perforating gun (20), which acts as a surge chamber. Subsequently, a fluid sample is flowed into the sampler (28).

ABSTRACT OF THE DISCLOSURE

An early evaluation system for use in a cased wellbore (12) is disclosed. The apparatus (10) comprises a tool string (18) with a perforating gun (20) on the lower end thereof. Tool string (18) also including a packer (24), a control valve (26), a sampler (28) and a locating device (36). As the apparatus (10) is run into the wellbore (14), the locating device (36) is used to locate the tool string (18) with respect to the formation (16). A second control valve (44) may be disposed above the sampler (28) so that fluid may be pumped down the tool string (18) and back into the formation (16) when the control valve (44) is opened. In operation, the perforating gun (20) is fired after the packer (24) is set, so that fluid initially flows into the spent perforating gun (20), which acts as a surge chamber. Subsequently, a fluid sample is flowed into the sampler (28).

EARLY EVALUATION SYSTEM FOR CASED WELLBORE

TECHNICAL FIELD OF THE INVENTION

The present invention relates in general to the early evaluation of a formation and, in particular, to the early evaluation of formation fluids in a well after the borehole has been drilled and casing cemented therein.

BACKGROUND OF THE INVENTION

During the drilling and completion of oil and gas wells, it is often necessary to test and evaluate the production capabilities of the well. This is typically done by isolating a subsurface formation or zone of interest which is to be tested and subsequently flowing a sample of well fluid either into a sample chamber or up through a tubing string to the surface. Various data such as pressure and temperature of the produced well fluids may be monitored downhole to evaluate the long term production characteristics of the formation.

One commonly used well testing procedure is to first cement a casing in the borehole or zone of interest. Subsequently, the well is flow tested through the perforations. Such flow tests are commonly performed with a drill stem test string which is a string of tubing located within the casing. The drill stem test string carries packers, tester valves, circulation valves and the like to control the flow of fluids through the drill stem test string.

Although drill stem testing of cased wells provides very good test data, it takes time to perforate the casing and then position and operate the drill stem test string. Better reservoir data can often be obtained shortly after the casing has been set rather than later. Therefore, there is a need for an apparatus and method for evaluating the well as early as possible.

SUMMARY OF THE INVENTION

The present invention disclosed herein is an early evaluation system for use in a cased wellbore which includes a gun, a packer, a sample chamber and logging-while-drilling telemetry equipment which allows quick correlation of the tool depth to insure that the proper formation or zone of interest is tested. More specifically, the apparatus comprises a tool string, a perforating gun on a lower end of the tool string, a packer having a set position for sealingly closing a well annulus between the tool string and the wellbore, a control valve adapted for controlling fluid flow between the gun and an upper portion of the tool string, a sampler disposed in the tool string and in communication with the control valve, and a logging-while-drilling or other logging device disposed in the tool string for generating data indicative of the nature of the subsurface formations intersected by the wellbore so that the tool string may be positioned adjacent to a specific formation or zone of interest. The packer, control valve and sampler are all disposed in the tool string. When the tool string is positioned using the logging-while-drilling device, and after the packer is set, the gun is fired to perforate the casing at the formation or zone of interest such that formation fluid will flow from the formation into the sampler after opening of the control valve.

The control valve is normally closed and is adapted for being opened after setting of the packer and firing of the gun. The sampler may include mini-samplers, such as the Halliburton pressure-actuated mini-samplers. The gun preferably comprises a surge chamber into which the formation fluid will flow prior to opening of the control valve.

The packer valve is normally closed and is adapted for being opened after setting of the packer and firing of the gun. The sampler may include mini-samplers, such as the Halliburton pressure-actuated mini-samplers. The gun preferably comprises a surge chamber into which the formation fluid will flow prior to opening of the control valve.

The packer may be a compression packer or hydraulic packer, and may be a straddle packer having a pair of spaced sealing elements thereon wherein the gun is disposed between the packer elements.

The apparatus may further comprise a receptacle in the tool string, and an inner well tool positionable in the tool string and adapted for connecting to the receptacle such that fluid may be flowed into the inner well tool. In one embodiment, the inner well tool is a length of tubing such that fluid may be flowed upwardly from the sampler through the tubing to the surface. In another embodiment, the inner well tool is a line-conveyed sampler which may be retrieved to the surface with a sample therein without removing the tool string from the wellbore. The line-conveyed sampler may comprise a pressure sensor and other fluid identification sensors.

In still another embodiment, the apparatus may comprise a second control valve above the sampler whereby fluid may be pumped down the tool string into the formation or zone of interest.

The early evaluation system of the present invention also includes a method of early evaluation of a well having a cased wellbore intersecting a subsurface formation or zone of interest. This method comprises the step of providing a testing string in the wellbore in which the testing string comprises a perforating device, a logging tool, a packer and a fluid testing device. The method further comprises the steps of logging the well with the logging tool and thereby determining the location of the subsurface formation or zone of interest, setting the packer into sealing engagement with the wellbore adjacent to the subsurface formation, firing the perforating device to perforate the casing and subsurface formation, flowing fluid from the subsurface formation and trapping a sample of the fluid in the fluid testing device.

The step of flowing fluid may comprise flowing fluid into a surge chamber defined in the perforating device. The step of trapping a sample of the fluid may comprise trapping the sample in a pressure-actuated sampler. The step of firing the perforating device may comprise applying annulus pressure to the perforating device or by other telemetry.

The method of the present invention may further comprise providing the testing string with a receptacle, running an inner well tool into the tool string and engaging the receptacle, and flowing a quantity of fluid into the inner well tool. In one embodiment, the inner well tool is a line-conveyed sampler and the step of flowing a quantity of fluid into the inner well tool comprises trapping a fluid sample in the line-conveyed sampler. In this embodiment, the method may further comprise the step of retrieving the line-conveyed sampler with the fluid sample therein to the surface. In another embodiment, the inner well tool is a length of coiled tubing and the step of flowing a quantity of fluid into the inner well tool comprises flowing fluid through the tubing to the surface to the surface or limited entry. The method may further comprise pumping fluid back into the subsurface formation by pumping fluid down the testing string.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, including its features and advantages, reference is now made to the detailed description of the invention, taken in conjunction with the accompanying drawings of which:

Figure 1 is a schematic illustration of an early evaluation system of the present invention after it has been run into the well to a position adjacent to a subsurface formation;

Figure 2 is a schematic illustration of the system of figure 1 after the packer has been set and the perforating gun fired;

Figure 3 is a schematic illustration of an early evaluation system of the present invention including a receptacle;

Figure 4 is a schematic illustration of the system of figure 3 with a slick-line-conveyed or wireline-conveyed sampler connected to the receptacle;

Figure 5 is a schematic illustration of the system of figure 3 with coiled tubing connected to the receptacle; and

Figure 6 is a schematic illustration of an early evaluation system of the present invention incorporating a straddle packer.

DETAILED DESCRIPTION OF THE INVENTION

While the making and using of various embodiments of the present invention is 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.

Referring now to the drawings, and more particularly to figure 1, an early evaluation system for a cased wellbore of the present invention is shown and generally designated by the numeral 10. Apparatus 10 is shown as it is run into casing 12 which is positioned in a wellbore 14 which intersects a subsurface formation or zone of interest 16. As used herein, “formation” will refer to any typical well formation or other zone of interest in a well.

Apparatus 10 is connected to the lower end of a testing or tool string 18 and thus may be considered a portion of the tool string. At the lower end of apparatus 10 is a perforating gun 20 having a plurality of perforating charges 22 therein. Preferably, but not by way of limitation, perforating gun 20 is a tubing-conveyed perforating (TCP) gun suitable for select firing in multiple zones on a single trip, such as the Vann Systems Vanngun. Disposed above perforating gun 20 is a packer 24, such as a Halliburton RTTS or CHAMP® packer.

Above packer 24 is a valve 26 which provides communication between packer 24 and the upper portion of tool string 18. Preferably, but not by way of limitation, valve 26 is a Halliburton perforate test sample (PTS) control valve which is opened after a predetermined time. Control valve 26 is originally closed as shown in figure 1.

A fluid testing device such as a sampler 28 is disposed above control valve 26 and defines a sample chamber 30 therein. As will be further described herein, a fluid sample from formation 16 may be received in sample chamber 30 when control valve 26 is opened.

If desired, a plurality of independently activated samplers 32, electronic or mechanical pressure and temperature recording instruments 34 or recorders 34, and other similar devices of identifying specific characteristics of the fluid sample from formation 16 may be disposed in sampling chamber 30. Samplers 32 may be similar to the Halliburton mini-samplers, and pressure and temperature recording instruments 34 may be similar to the Halliburton HMR. Examples of mini-samplers are shown in U.S. Patent Nos. 5, 240,072; 5,058,674; 4,903,765 and 4,787,447, which are incorporated herein by reference. Recorders 34 may include an electronic memory recording fluid resistivity tool, such as manufactured by Sondex or Madden. Samplers 32 and instruments 34 are in fluid communication with control valve 26 through sample chamber 30.

Also disposed in tool string 18 is a logging tool 36 having instrumentation used to correlate the depth of the tool string to insure that the proper formation 16 is tested. This instrumentation may be of the type generally referred to as a logging-while-drilling device. Typically, a logging-while-drilling device contains instrumentation for logging subterranean formations during drilling. As such, when a formation has been intersected by the wellbore being drilled, the formation is logged while the drill string is being raised, whereby the logging-while-drilling device is moved through the formation. Logging tool 36 provides constant remote communication with a surface command station by means of a remote communication system such as further described herein.

In operation, apparatus 10 is run into casing 12 in wellbore 14. Telemetry from logging device 36 provides the operator with the necessary information as to when apparatus 10 is adjacent to formation 16. Thus, apparatus 10 is quickly and easily positioned at the desired location in wellbore 14.

Referring now to figure 2, packer 24 is set into sealing engagement with the inside of casing 12 at a position at or near the upper portion of formation 16. Perforating gun 20 is fired, such as by applying annulus pressure on other telemetry. That is, perforating charges 22 are triggered so that perforations 38 are created through casing 12 and into formation 16 in a manner known in the art. Upon the firing of perforating charges 22, an opening 40 is created in perforating gun 20 at the location of each of perforating charges 22 such that flow from formation 16 may enter the spent gun 20.

Perforating gun 20 is initially empty, but the firing of perforating charges 22 creates openings 40 that allows the gun to act as a surge chamber which quickly fills because of formation pressure from formation 16. Initially, “dirty” fluid will flow through openings 40 and into the spent gun 20. Eventually, after a period of time, clean fluid will flow from formation 16.

After the time delay necessary for clean fluid to flow from formation 16, control valve 26 is opened to create a flow path 42 therethrough which is in communication with sample chamber 30 in sampler 28. At any desired time, any of mini-samplers 32 may be activated and a sample of fluid taken by flowing into sampler 32. Operation of any of mini-samplers 32 is optional.

If desired, the measurement of zone pressures, temperatures or other parameters by recorders 34 may be carried out with or without capturing a sample in a mini-sampler 32. That is, recorders 34 may be activated to take the appropriate pressure/temperature measurements as desired and send them to the surface. The operation of mini-samplers 32 and recorders 34 is known in the art.

After completion of the test, apparatus 10 is retrieved to the surface. At this point, the fluid in sample chamber 30 and in mini-samplers 32 may be drained on location, or the contents thereof may be transferred to a sample bottom for local evaluation or shipment to a pressure-volume-test (PVT) laboratory, or the entire sampler 28 may be shipped to a PVT laboratory for fluid transfer and testing. The data obtained by recorder 34 is also analyzed to determine various properties of the formation fluids.

A control valve 44 is disposed above sampler 28 and is initially in the closed position shown in figure 1. If desired, after a fluid sample has been captured in sampler 30 as previously described, control valve 44 may be actuated to its open position so that a flow path 46 is provided in communication with central opening 48 in tool string 18. In this configuration, fluid may be pumped down tool string 18 through flow path 46 in opened controlled valve 44 and thus through sampler 28, flow path 42, packer 24 and openings 40 in perforating gun 20. Thus, formation fluid may be forced back into formation 16 in an operation known as "bull-heading." The formation pressure could then be monitored at the surface to insure that the hydrostatic pressure in the well will keep the formation fluid from blowing out. Also, if the well is found to be sour, the produced fluid may be pumped back into the formation. In this way, the disposal costs and hazard of bringing a large sour gas sample to the surface are greatly reduced or eliminated.

Referring now to figure 3, a cased hole early evaluation system of the present invention is shown and generally designed by the numeral 50. Apparatus 50 includes all of the same components as apparatus 10, namely a perforating gun 20, a packer 24, a control valve 26, a sampler 30 and a logging device 36.

Apparatus 50, however, includes a coiled tubing receptacle 52 disposed between sampler 28 and logging device 36. As will be further described herein, receptacle 52 is adapted for receiving an inner well tool.

In operation, apparatus 50 is run into casing 12 and wellbore 14 in a manner similar to that of apparatus 10. Logging device 36 allows the operator to quickly and easily position apparatus 50 in the desired location adjacent to formation 16. Packer 24 is actuated into sealing engagement with casing 12, and perforating gun 20 is operated to form perforations 38. Spent gun 20 then acts as a surge chamber for initial "dirty" fluid flowing from formation 16 into the gun through openings 40. Samples may then be taken in sampling chamber 30 and in mini-samplers 32, and pressure and temperature measurements and other fluid measurements may be taken and recorded by recorders 34 as previously described.

Referring now to figures 4 and 5, two variations of apparatus 50 are shown. In the first variation, as shown in figure 4, an inner well tool is a line-conveyed tool such as a sampler 54 that may be lowered into receptacle 52 on a slick line or wireline 56. Sampler 54 may include a pressure sensor or other fluid identification sensors or gage 57 thereon and has a stinger 58 thereon adapted for engagement with receptacle 52 and for being received therein. When in this position, sampler 54 is thus placed in fluid communication with formation 16 so that the sampler can be used to collect a fluid sample which can then be brought to the surface by retrieving sampler 54 with the slick line or wireline 56. In this way, the operator is able to get a small sample to evaluate, as well as check pressures either in real time or upon receiving the gauges back at the surface.

Referring now to figure 5, the second variation of apparatus 50 is shown. In this case, the inner well tool is characterized by an inner coiled tubing string 60 with a stinger 62 at the lower end thereof. In this embodiment, when coiled tubing string 60 is run into tool string 18, and stinger 62 engaged with and received by receptacle 52, fluid from formation 16 may be flowed upwardly through the coiled tubing string to a surface location on limited entry. Also, treatment fluids can be pumped down through the coiled tubing string into formation 16.

Referring now to figure 6, a cased hole early evaluation system of the present invention is shown and generally designated by the number 64. Apparatus 64 is essentially the same as apparatus 10 except that it includes a straddle packer with upper and lower packer elements 68 and 70 which can be used to provide a seal above and below formation 16. Otherwise, operation of apparatus 64 is identical to that of apparatus 10.

It will be seen, therefore, that the cased hole early evaluation system of the present invention is well adapted to carry out the ends and advantages mentioned as well as those inherent therein. While presently preferred embodiments of the apparatus have been shown for the purposes of this disclosure, numerous changes in the arrangement and construction of parts may be made by those skilled in the art. All such changes are encompassed within the scope and spirit of the appended claims.

What is claimed is:

1. An apparatus for use in testing a cased wellbore, the apparatus comprising:

a tool string;

a perforating device on a lower end of the tool string;

a packer, carried on the tool string, having a set position for sealingly closing a well annulus between the tool string and the cased wellbore;

a control valve disposed in the tool string operably controlling fluid flow therethrough;

a sampler disposed in the tool string and in communication with the control valve; and

a locating device disposed within the tool string for selectively positioning the tool string adjacent to a formation;

wherein, when the tool string is so positioned, the packer is set and the control valve is in communication with the formation, formation fluid will flow from the formation into the sampler after opening the control valve.

2. The apparatus of claim 1 wherein the control valve is a normally closed valve adapted for being opened after setting of the packer and operating the perforating device.

3. The apparatus of claim 1 wherein the sampler may be opened to take a fluid sample after a predetermined time.

4. The apparatus of claim 3 wherein the sampler is a pressure-actuated sampler.

5. The apparatus of claim 1 wherein the perforating device is fired by applying pressure thereto through the well annulus.

6. The apparatus of claim 1 wherein the packer is a compression packer.

7. The apparatus of claim 1 wherein the packer is a straddle packer having a pair of spaced sealing elements thereon and the perforating device is disposed between the sealing elements.

8. The apparatus of claim 1 wherein the perforating device comprises a surge chamber into which the formation fluid will flow prior to opening of the control valve.

9. The apparatus of claim 1 further comprising a receptacle in the tool string and an inner well tool positionable in the tool string and adapted for connecting to the receptacle such that fluid may be flowed into the inner well tool.

10. The apparatus of claim 9 wherein the inner well tool is a length of tubing such that fluid may be flowed upwardly from the sampler through the tubing.

11. The apparatus of claim 9 wherein the inner well tool is a line-conveyed sampler which may be retrieved to the surface with a sample therein without removing the tool string from the wellbore.

12. The apparatus of claim 11 further comprising a pressure sensor on the line-conveyed sampler.

13. The apparatus of claim 1 further comprising a second control valve disposed within the tool string whereby fluid may be pumped down the tool string into the formation.

14. A method of early evaluation of a well having a cased wellbore intersecting a formation, the method comprising the steps of:

(a) providing a tool string in the wellbore comprising a perforating device, a packer, a control valve, a sampler and a locating device;

(b) determining the location of the formation with a locating device;

(c) setting the packer into sealing engagement with the cased wellbore adjacent to the formation;

(d) operating the perforating device to perforate the casing and the formation;

(e) flowing fluid from the formation; and

(f) trapping a sample of the fluid in the sampler.

15. The method of claim 14 wherein step (f) comprises trapping the sample in a pressure-actuated sampler.

16. The method of claim 14 wherein step (e) comprises flowing fluid into a surge chamber defined in the perforating device.

17. The method of claim 14 wherein step (d) comprises applying annulus pressure to the perforating device.

18. The method of claim 14 wherein step (c) includes sealingly engaging the packer above and below the formation.

19. The method of claim 14 further comprising in step (a), providing the testing string with a receptacle,(g) running an inner well tool into the tool string and engaging the receptacle and (h) flowing a quantity of fluid into the inner well tool.

20. The method of claim 19 wherein the inner well tool is a line-conveyed sampler and wherein step (h) comprises trapping a fluid sample in the line-conveyed sampler.

21. The method of claim 20 further comprising (i) retrieving the line-conveyed sampler with the fluid sample therein to the surface.

22. The method of claim 19 wherein the inner well tool is a length of coiled tubing and step (h) comprises flowing fluid through the tubing to the surface.

23. The method of claim 14 further comprising (g) pumping fluid back into the subsurface formation by pumping fluid down the testing string.

24. The method of claim 14 wherein step (f) comprises opening a valve in communication with the fluid testing device after a predetermined time after step (e).

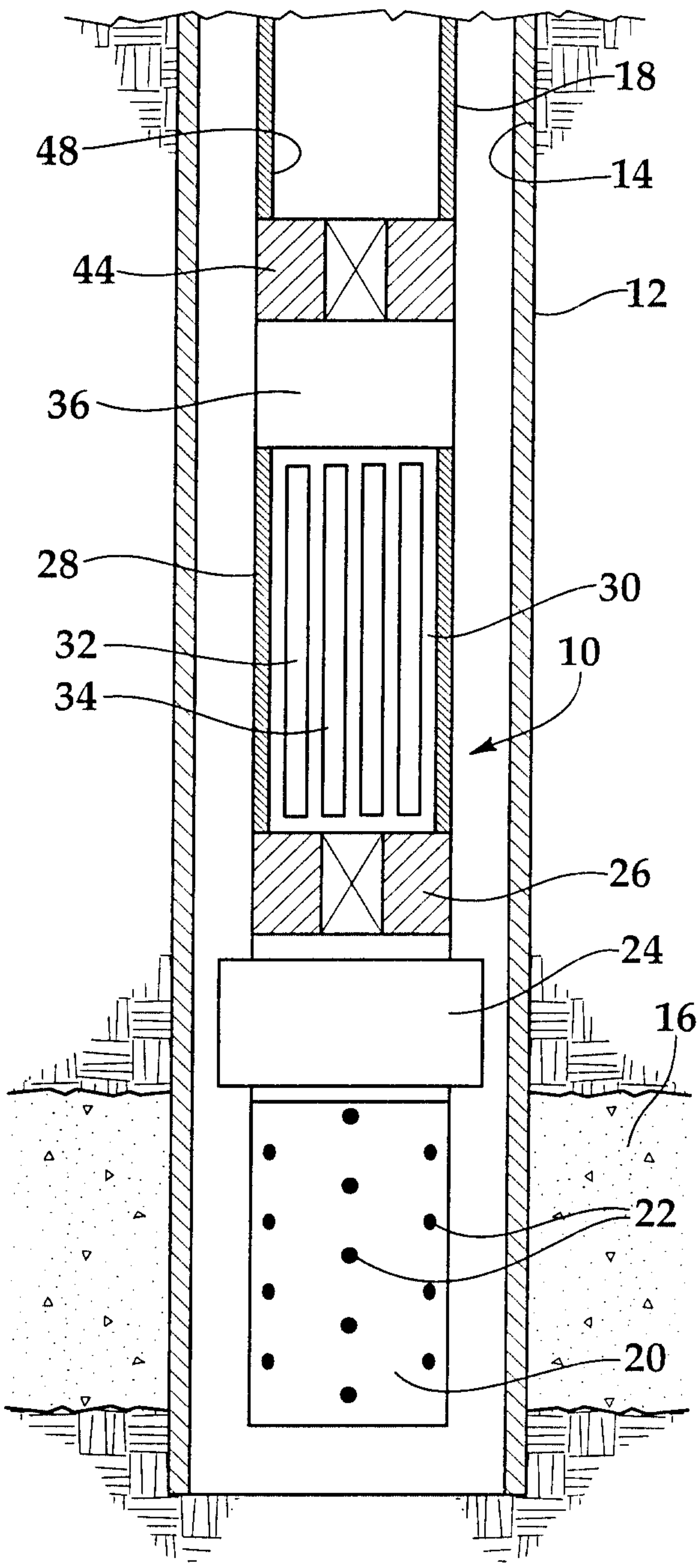

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Fig.1

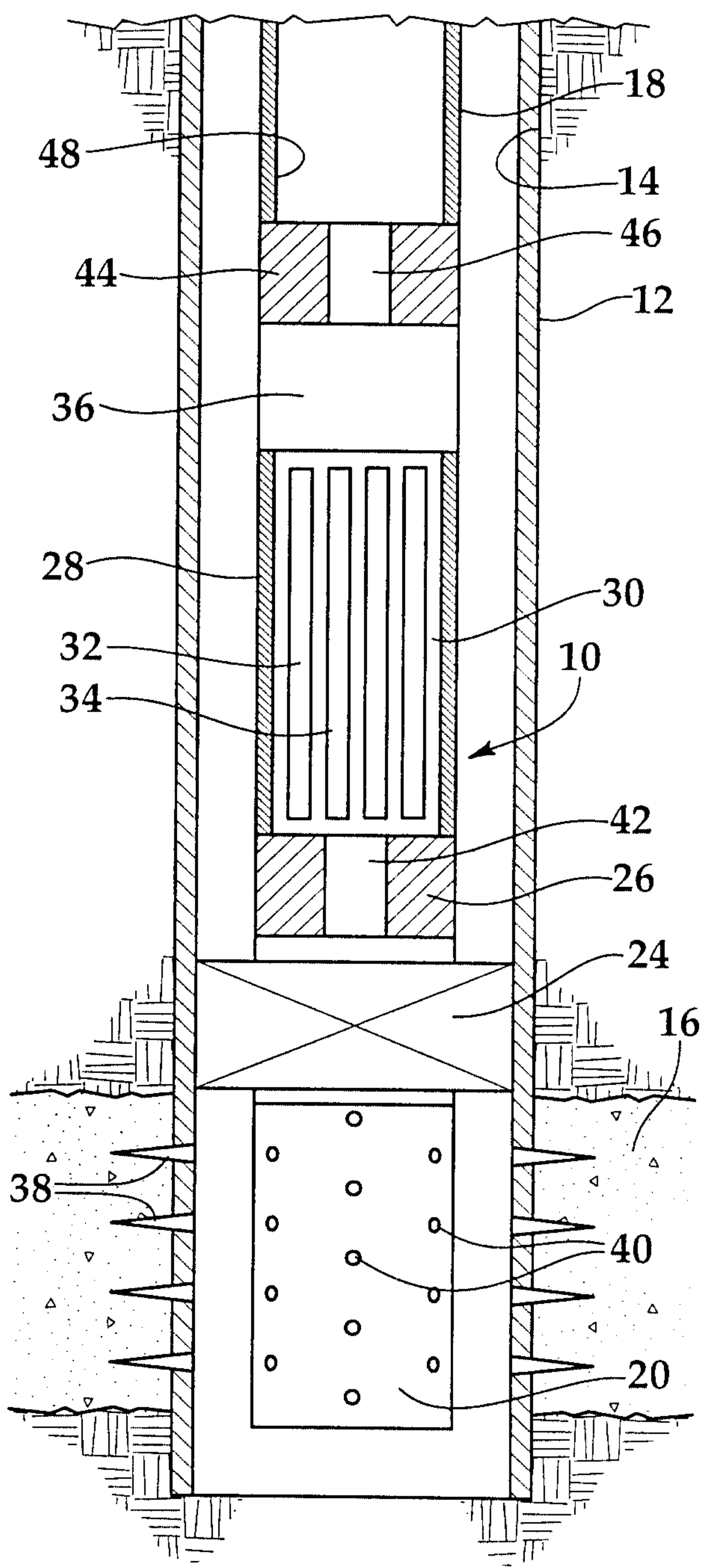
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Fig.2

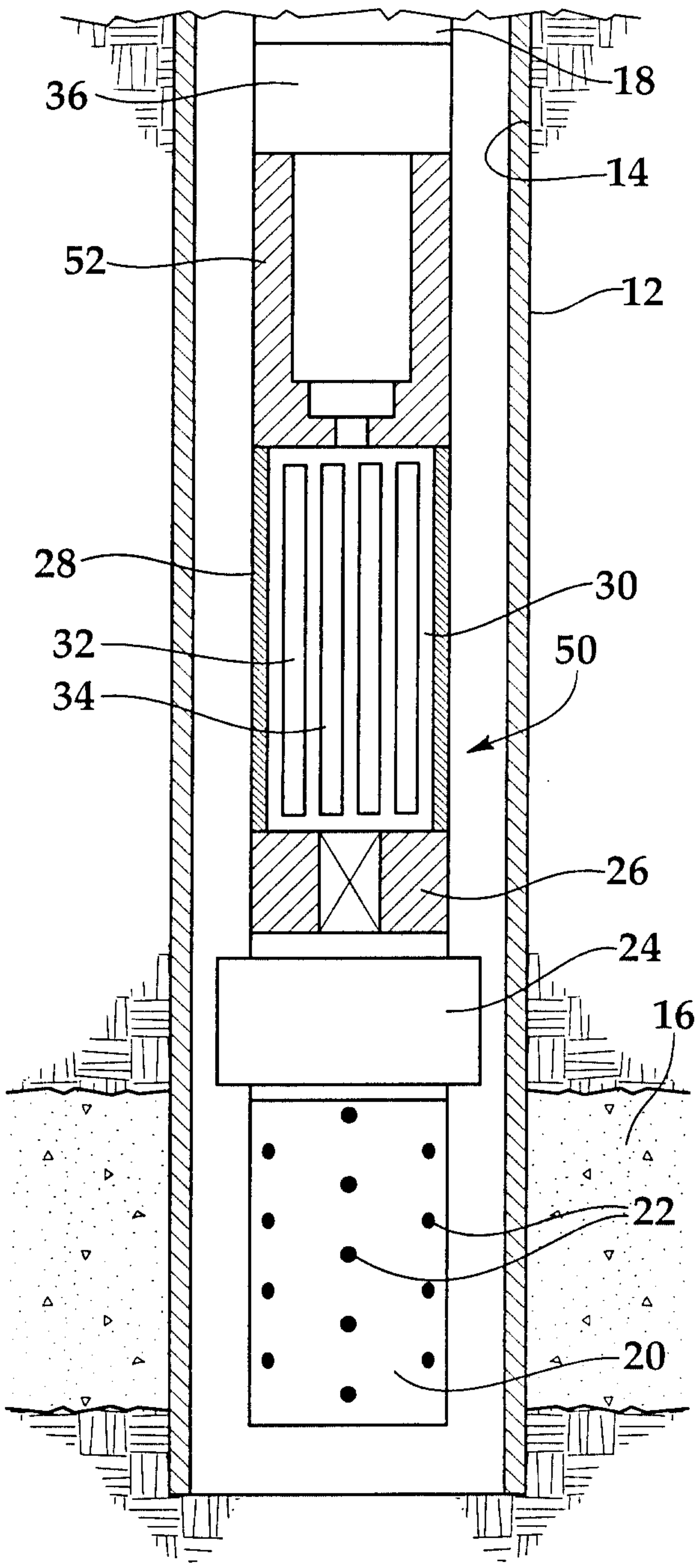

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Fig.3

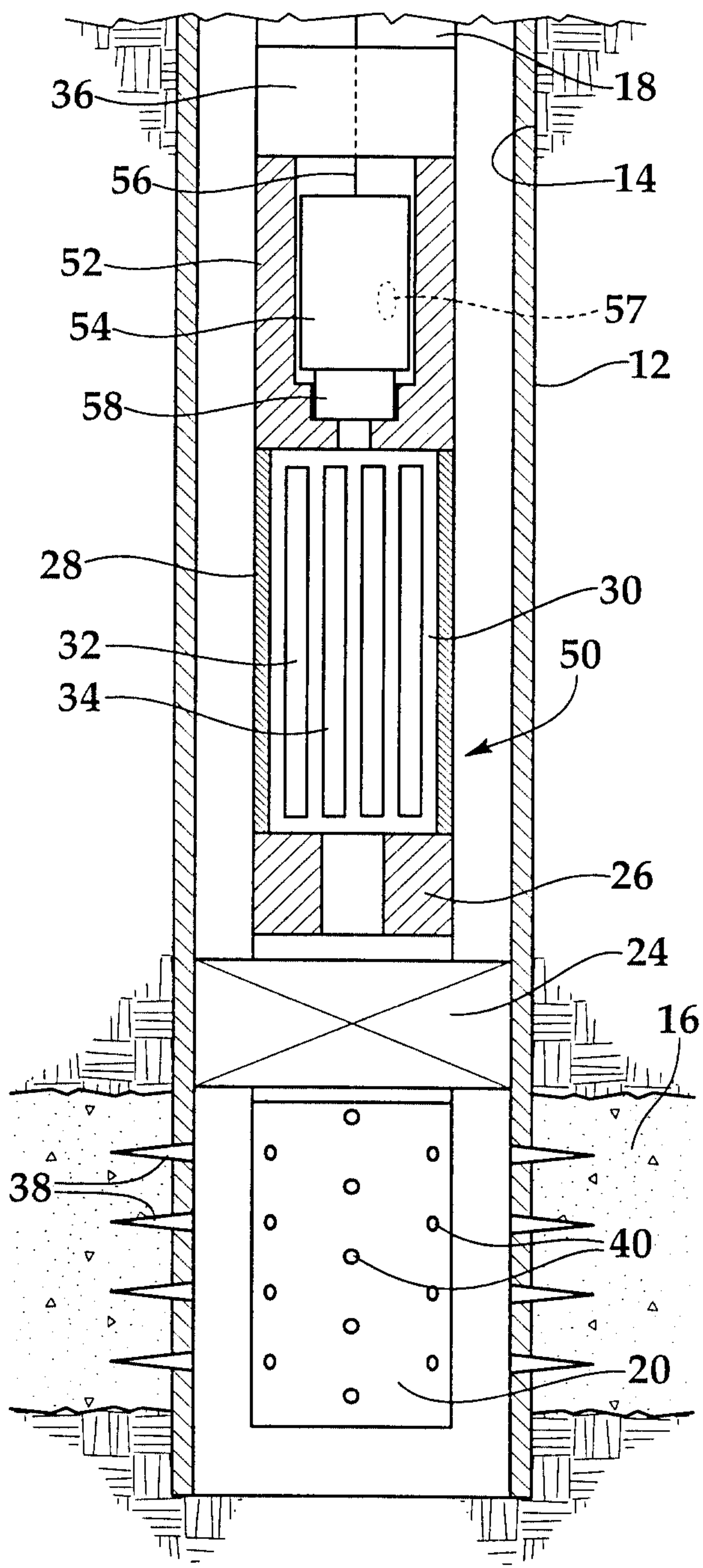

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Fig.4

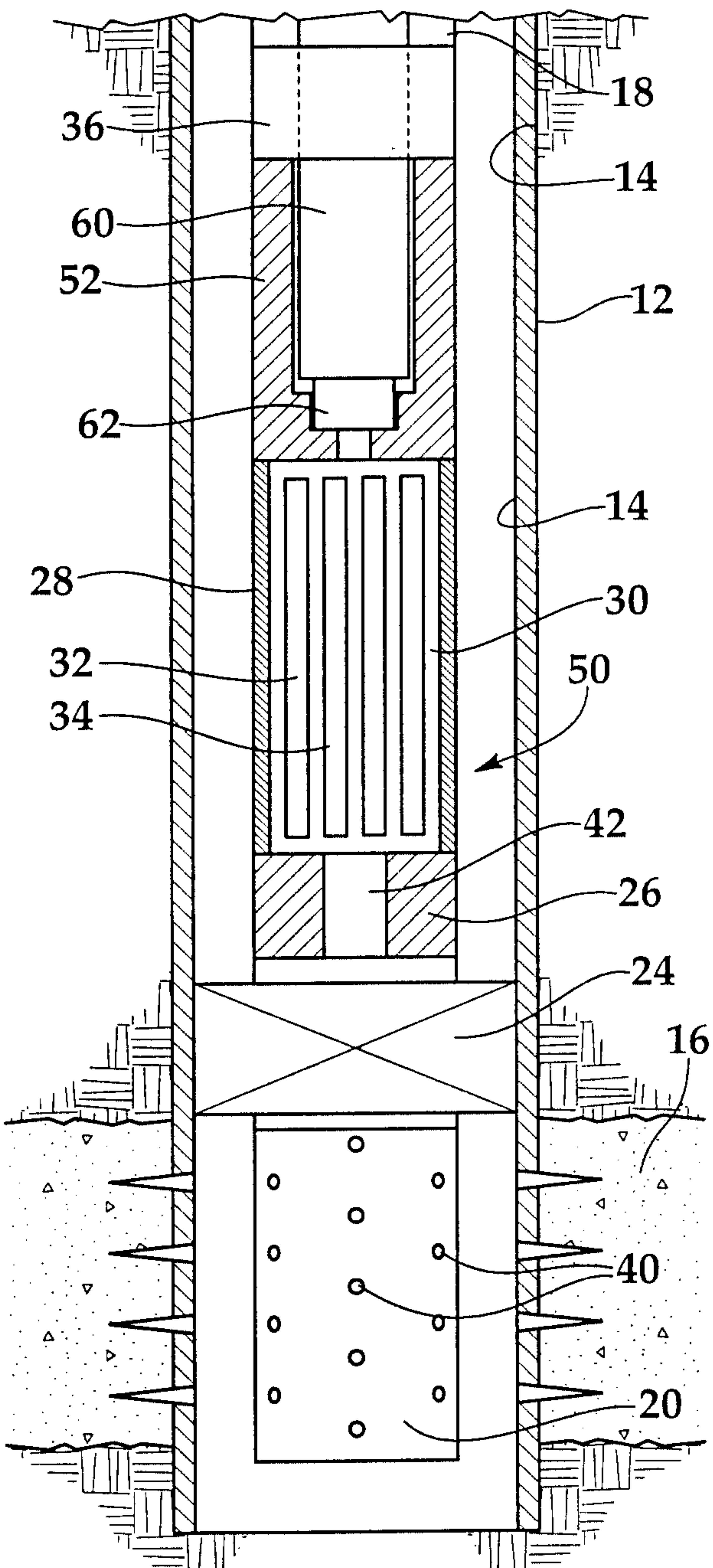
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Fig.5

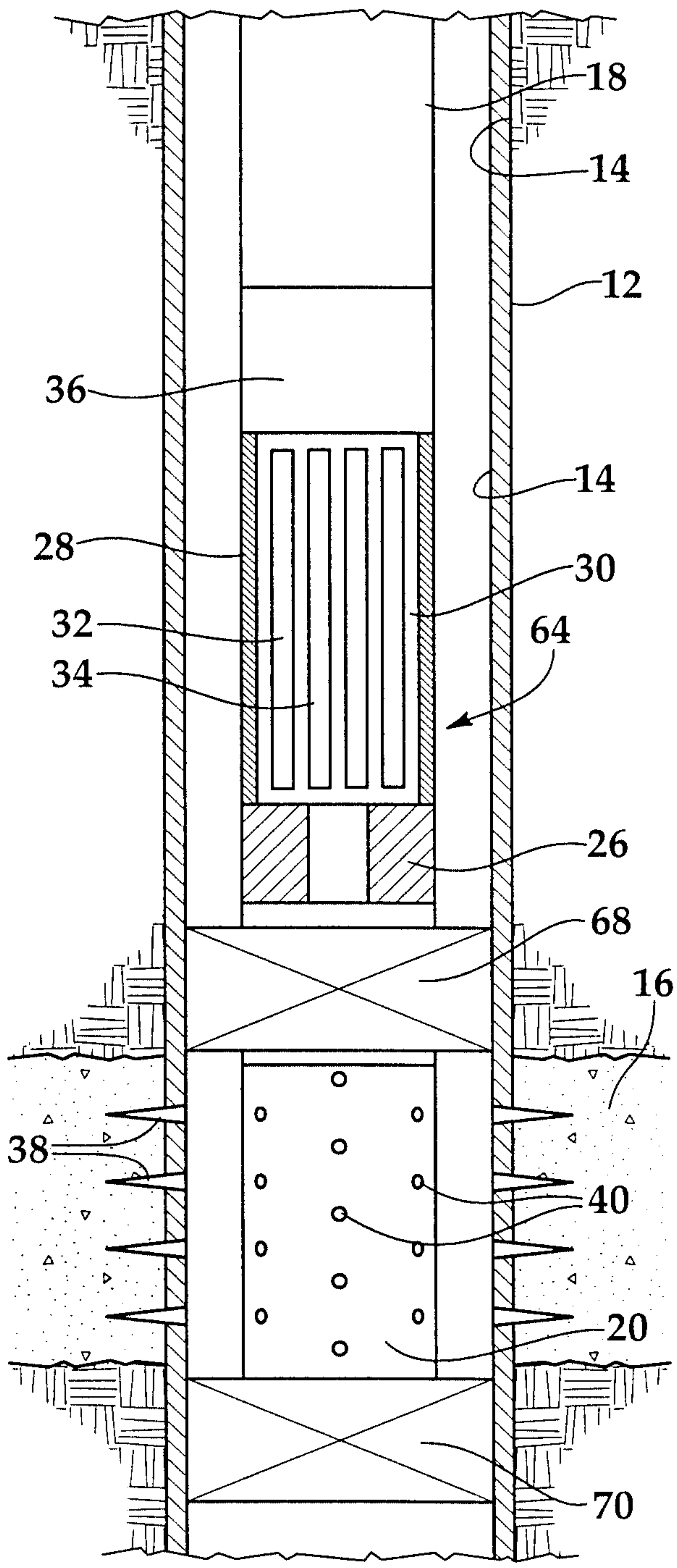
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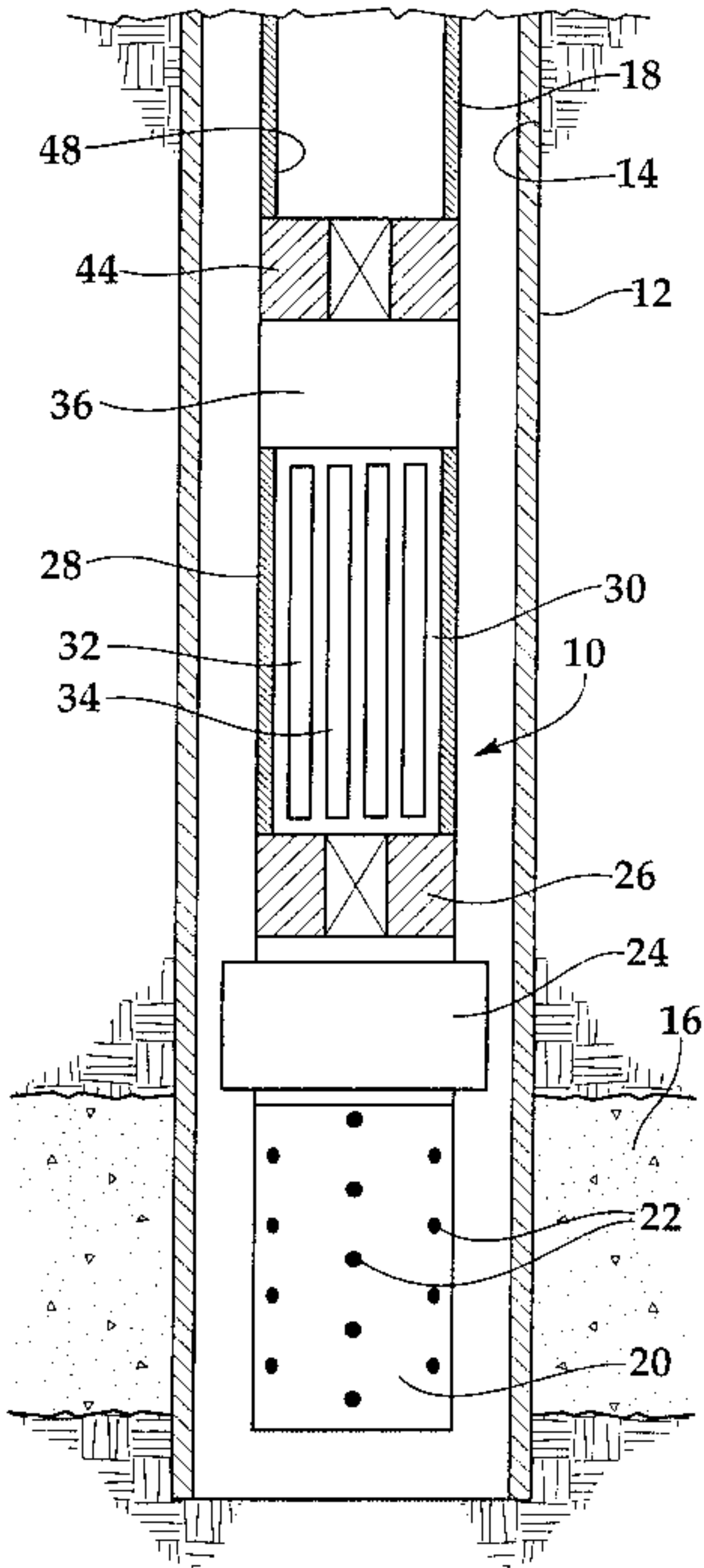
Fig.6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