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(54) **Monitoring sand screen**

Überwachung eines Sandfilters

Surveillance d'un tamis à sable

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(56) References cited:
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Description

[0001] This invention relates to a method of monitoring sand screens.

[0002] Oil, gas or water wells are conventionally drilled with a drill string, which comprises drill pipe, drill collars and drill bit(s). The drilled open hole is hereinafter referred to as a "borehole". A borehole is typically lined with casing sections, liners and/or production tubing. The casing is usually cemented in place to prevent the borehole from collapse and is usually in the form of one large diameter pipe.

[0003] Migration of sand into production tubulars and surface equipment can cause catastrophic damage and in the worst case completely block hydrocarbon production. To avoid these unwanted events, sand producing wells are often choked back or shut-in with the unfortunate effect of reducing revenues for the well owner.

[0004] However, many wells drilled into unconsolidated sand formations are now completed with sand screens to limit the entry of sand grains produced with the hydrocarbons. The sand screen is a type of mesh on a perforated base pipe and prevents sand and rocks from collapsing into and blocking the well bore. Sand screens are often installed in open hole completions in a final drilled, uncased reservoir section. These maintain structural integrity of the borehole in the absence of casing, while still allowing flow from the reservoir into the borehole. Gravel packing is often used to supplement the sand filtering process

[0005] Typically, sand screens are constructed using two main elements:

- (i) mechanical filter, such as mesh or wire wrap, to block entry of particles above a certain minimum size;
- (ii) a supporting pipe which has a series of holes or slots to allow entry of the particle free hydrocarbon

[0006] Sand screens are available in many sizes, varieties and makes but essentially, all are filters to control the passage of formation sands into the borehole.

[0007] Sand screens therefore control the migration of formation sands into production tubulars and surface equipment, which can cause washouts and other problems, particularly from unconsolidated sand formations in many fields.

[0008] Sand screens are however susceptible to damage from sand particle erosion or other damage. When damage occurs, it allows sand to penetrate the completion causing many problems in the well's completion elements and surface pipework and plant.

[0009] According to a first aspect of the present invention there is provided a method to monitor the integrity of a sand screen, the method comprising:

- (a) directing at least one electromagnetic wave towards a sand screen inside a borehole;

- (b) detecting at least one reflected or emitted electromagnetic wave from said sand screen inside the borehole in order to produce at least one data measurement.

[0010] In normal, uniformly smooth walled pipe such as tubing or casing (as opposed to a sand screen of the present invention) various electromagnetic devices are used to measure wall thickness. Certain devices use a transmitter to emit an alternating magnetic wave which permeates through the pipe wall and travels a short distance along the outside before passing back through to be detected by an array of sensors. The velocity and amplitude of the emitted wave are affected by the metal thickness; thinner walls resulting in faster wave propagation and less attenuation. These results are used to detect and quantify mechanical variations in the pipe's structure.

[0011] In marked contrast, the nature of sand screens is not at all uniformly smooth being constructed with a series of high density perforations and so such a technique clearly appears unsuitable to monitor sand screens. The skilled person would be dissuaded from such use since the signal reflected or emitted from the device would have no clear route through the mesh or slotted pipe of the sand screen and the resulting data would be so full of 'noise' that it would not be expected to be useful.

[0012] Against these expectations the inventors of the present invention have surprisingly found that useful information can in fact be taken from such monitoring, and that damage to the sand screen can be detected. To do this a sand screen is analysed according to the first aspect of the invention.

[0013] Preferably step (a) is a logging step.

[0014] Preferably there is a plurality of electromagnetic waves directed towards the sand screen in step (a), thus forming a scan of said sand screen.

[0015] Typically steps (a) and (b) are done after the borehole has been in use, that is producing fluids, for a period of time such as more than 1 day, typically more than 6 months, often more than 3 years; or alternatively when it is thought there may be damage to the sand screen for any reason.

[0016] In preferred embodiments, a sand screen is monitored outwith a borehole, and the results from this monitoring compared to a sand screen monitored in accordance with the first aspect of the present invention. Thus preferably further steps (i) and (ii) are also conducted, steps (i) and (ii) being:

- (i) directing at least one electromagnetic wave towards a sand screen under controlled conditions outside of a borehole; and
- (ii) detecting reflected or emitted electromagnetic wave from said sand screen in order to produce at least one data measurement.

[0017] Preferably steps (i) and (ii) and conducted before steps (a) and (b).

[0018] Preferably step (i) is a logging step.

[0019] Preferably there is a plurality of electromagnetic waves directed towards the sand screen in step (i), thus forming a scan of said sand screen.

[0020] Preferably the sand screen in steps (i) and (ii) is an undamaged sand screen.

[0021] The results detected in step (ii) may be referred to as a 'signature' or "finger print" result of the sand screen. The results found in step (ii) may be also referred to as a "baseline" result.

[0022] The method of the invention may include deploying the sand screen from step (ii) into the borehole.

[0023] The method of the invention may include producing fluid, especially hydrocarbons, from the borehole after step (ii) and before step (a).

[0024] Preferably the sand screen in step (i) and (ii) is the same sand screen as that in steps (a) and (b) - the difference being that the sand screen is outwith the borehole in steps (i) and (ii) and inside the borehole in steps (a) and (b).

[0025] Step (i) may be prior to deployment of a sand screen in a borehole. However for some alternative embodiments, a sand screen may, for example, be already deployed in a borehole without steps (i) and (ii) performed. For such or other embodiments, steps (i) and (ii) can be taken from another screen, preferably the same type of screen as that in the borehole, after deployment of a sand screen in a borehole. Indeed for certain embodiments steps (a) and (b) are not necessarily performed after steps (i) and (ii), they may be performed before steps (i) and (ii).

[0026] 'Outside of a borehole' is typically on land or on a platform or ship.

[0027] Preferably the method also includes:

(c) data processing and analysis of the comparison between the data measurements in step (ii) and step (b).

[0028] The data processing and analysis of step (c) normally includes comparison between the data measurements in step (ii) and step (b).

[0029] Data processing and analysis may be performed on any difference determined in step (c) to determine and preferably quantify the location of damaged areas.

[0030] Preferably a tool is used to direct the electromagnetic wave towards the sand screen in steps (i) and (a) and detect any reflection in steps (ii) and (b).

[0031] The tool may be an electronic logging tool. Electromagnetic logging tools have hitherto been used to measure thickness of tubing (production tubing and liner and casing for example) in order to measure the corrosion on either the inside or the outside of solid pipe. However their use on a sand screen is unprecedented and surprisingly effective.

[0032] A variety of logging tools may be used, but preferably the same tool is used in each of steps (i), (ii), (a) and (b).

[0033] Typically the tool comprises at least one emitter and at least one detector.

[0034] There may be one emitter and a plurality of detectors, such as more than 5 detectors, preferably more than ten detectors and one certain embodiment comprises twelve detectors.

[0035] Preferably the tool emits and detects alternating magnetic fields/waves. Preferably therefore the tool is an electromagnetic tool.

[0036] Preferably the electromagnetic wave is of a frequency in the range of 5 to 20 Hz. The wave permeates through the sand screen wall and travels a short distance along the outside before passing back through to be detected by the at least one sensor of the tool.

[0037] The phase and amplitude of the emitted wave are affected by the metal thickness; thinner walls resulting in faster wave propagation and less attenuation. These differences are used to detect and quantify mechanical variations in the pipe's structure.

[0038] The tool may also comprise a device which measures the internal profile of the sand screen. The tool may comprise a set of arms which may be activated from the logging system or by the memory tool to open the arms. Preferably the tool comprises callipers. This can provide information on the inner diameter of the sand screen.

[0039] By combining information from the two tools, images can be created on a computer screen in three dimensions.

[0040] Preferably the tool comprises an inclinometer to indicate the arm positions relative to the high side of the pipe, so that features can be orientated correctly during data processing.

[0041] A continuous measurement of the pipe's surface condition is made as the tool is logged.

[0042] Thus damage, including corrosive damage, may be located using method in accordance with the present invention.

[0043] An embodiment of the present invention will now be described, by way of example only, and with reference to the accompanying figures in which:

Fig. 1 is a view of an electromagnetic logging tool used in accordance with the present invention;

Fig. 2 is a scan of an undamaged sand screen;

Fig. 3 is a scan of a damaged sand screen.

[0044] An electromagnetic (EM) logging tool 10 as shown in Fig. 1 has one emitter 12, twelve sensors 14 mounted on bowsprings 16 and is provided within a sand screen 18 in a wellbore 19. The electromagnetic tool used in preferred embodiments of the invention may be obtained from GE Energy (formerly Sondex) and is known as the Magnetic Thickness Tool (MTT).

[0045] The EM logging tool is used to scan a portion

of a sand screen at the surface before it is deployed in the well. After the sand screen has been in used in the well it may be scanned again to check for damage or specifically locate damage which may have been observed by sand production or other problems.

[0046] As shown in Fig. 1, the emitter 12 emits an alternating magnetic field 17 which travels through the sand screen 18. The technique is called the Remote Field Eddy Current method. The emitted EM field 17 travels through the pipe wall and sets up eddy currents which prevents re-entry of the signal until such time that the strength of the wave (and the induced eddy currents) have decayed sufficiently to allow the wave to travel back through the pipe - it therefore makes two transits across the sand screen thickness. The sensors 14 are spaced away from the emitter 12 such that they match the decay and are positioned optimally to capture the returning wave. The wave 17 at a damaged area (the inner wall) 15 returns faster in comparison to the other points in the same circumference and with higher amplitude. By measuring the transit time (which is related to phase of the sinusoid) a mathematical relationship allows an estimation of damage. Optionally this can be combined with other data from callipers, described below.

[0047] By visually comparing the individual fingerprints of in-situ sand screens with the pre-logged signature of a new and undamaged screen of the same type, differences are clearly identifiable, which, by inference must represent damage to the screens. These differences therefore pinpoint the depth of damaged areas and allow appropriate remedial action to be taken.

[0048] This information allows remedial work to be carried out to repair or block off the damaged section of sand screen. The electronic logging tools are capable of identifying the location of the damage, characterising the type of damage and quantifying the extent of the damaged area.

[0049] The EM logging tool 10 is also coupled with an electromechanical device such as callipers (not shown) to measure internal wall profile when the scan is performed downhole and along with the EM tool 10 provides useful information. One suitable tool may be a Multifinger Calliper tool.

[0050] Using the EM logging tool described above, a series of tests was conducted under controlled conditions to obtain the signatures of a variety of undamaged sand screens. Data was obtained in both logging directions and at a range of speeds and operating parameters to obtain the best possible images of the sand screens - the raw data being displayed on scaled plots labelled with the key match points and elements making up the screen. A library of signatures was thus obtained for later use in the field for comparison purposes - see figure 2 for a scan of a common type of sand screen logged with the electromagnetic tool.

[0051] A second series of fingerprints was obtained from the same screens with deliberately induced damage of known nature and dimensions in order to provide better

characterisation of the damage when found on logged data and to provide data may allow a predictive element for possible early indication of potential damage. The types of damage induced included full wall penetration, partial wall penetrations, cut slots and holes of different dimensions, gouges and dents. The penetrative damage was performed by a sand blasting device, a mechanism similar in nature to actual damage commonly observed in deployed screens. The gouges and dents were included as indications of damage sustained during the deployment of the screens during well completion - see Fig. 3 for a typical scan of 100% and 50% penetrations of the sand screen.

[0052] Comparing the scans in Figs. 2 and 3, joints between adjacent sand screens can be observed referenced 22, as well as a weld band 24. However the differences in the scans 20 are indicative of damage to the screens. Thus certain embodiments of the present invention provide a new method to enable damaged sand screens to be identified in a consistent and reliable manner.

[0053] Indeed in the example of Fig. 2 it would be possible to ascertain that damage had occurred even without reference to Fig. 3. In certain situations this would not always be possible since it may be unclear from a single scan in itself where damage had occurred. Even if possible, it would normally be easier to make a reference scan to highlight any changes. Thus whilst certain embodiments do not require a reference or baseline scan, it is preferable to use one.

[0054] Thus comparison of fingerprints and signatures of new and in-situ screens may be performed using EM logging tools. Also certain embodiments using EM logging tools provide additional benefits in terms of economics, flexibility, ease of deployment.

[0055] The EM logging tool may be deployed in a surface read out or a memory mode. It can obtain consistent data while travelling either downwards or upwards in the well, is easy to deploy (light and short), centralisation is noncritical, can gather the same data with the well shut in or flowing, operates equally well in gas or liquid and has a smooth mode of travel on bowspring arms therefore eliminating road noise against the irregular surface of a typical sand screen.

[0056] Other logging tools could be deployed but are less preferred. Various factors are important when considering a suitable tool. These factors include:

- well state (flowing or shut in - Production Logging Tools)
- size and dimension (long and/or large diameter tools)
- well fluid (ultrasonic tools only operate in liquid)
- dedicated SRO (memory tools may be easier to deploy in certain situations eg with coiled tubing)
- need to be well centralised (Production Logging Tools)
- road noise (tools with fingers/arms or roller central-

isers)

[0057] Thus certain other tools may be used for alternative embodiments of the invention.

[0058] The embodiments of the invention provide a new method of identifying damage to sand screens by comparison of reference signatures (or fingerprints) of new, undamaged sand screens to that of deployed, in-situ sand screens has been demonstrated through the technique of pattern recognition. Early indication of potential damage and sand breakthrough may be a beneficial outcome of the analysis.

[0059] In summary, embodiments of the invention relate to a technique of using electromagnetic logging tools to identify areas of damage in sand screens after deployment in a borehole. In particular, the "noise" in a tool response from a logging pass can be compared to a tool response from screens of known condition. The sand screens of known condition are logged in a controlled environment. The condition is then changed by imparting mechanical damage to the screen. The variation from pristine condition can be assessed for a sand screen installed in a well. The identification of location of damage in a well and potentially the level of damage means a series of solutions can be, with the agreement of the well owner, constructed to improve well (productivity) performance.

[0060] Improvements and modifications may be made without departing from the scope of the invention.

Claims

1. A method to monitor the integrity of a sand screen, the method comprising:
 - (a) directing at least one electromagnetic wave towards a sand screen inside a borehole;
 - (b) detecting at least one reflected or emitted electromagnetic wave from said sand screen inside the borehole in order to produce at least one data measurement.
2. A method as claimed in claim 1, wherein step (a) is a logging step.
3. A method as claimed in either preceding claim, wherein there is a plurality of electromagnetic waves directed towards the sand screen in step (a), thus forming a scan of said sand screen.
4. A method as claimed in any preceding claim, wherein steps (a) and (b) are done after the borehole has been in use, that is producing fluids, for more than 1 day, optionally more than 6 months, often more than 3 years.
5. A method as claimed in any preceding claim, includ-

ing:

- (i) directing at least one electromagnetic wave towards a sand screen under controlled conditions outside of a borehole; and
- (ii) detecting at least one reflected or emitted electromagnetic wave from said sand screen in step (i) in order to produce at least one data measurement.

6. A method as claimed in claim 5, wherein steps (i) and (ii) are conducted before steps (a) and (b).
7. A method as claimed in claim 5 or claim 6, wherein the sand screen in step (i) and (ii) is the same sand screen as that in steps (a) and (b).
8. A method as claimed in any one of claims 5 to 7, comprising producing fluid, especially hydrocarbons, from the borehole after step (ii) and before step (a).
9. A method as claimed in any one of claims 5 to 8, the method also including:
 - (c) data processing and analysis of the comparison between the data measurements in step (ii) and step (b).
10. A method as claimed in any one of claims 5 to 9, wherein an electronic logging tool directs the electromagnetic wave towards the sand screen in steps (i) and (a) and detect any reflection in steps (ii) and (b).
11. A method as claimed in claim 10, wherein the tool comprises at least one emitter and more than 5 detectors, optionally more than ten detectors.
12. A method as claimed in any one of claims 10 to 11, wherein the tool comprises a device which measures the internal profile of the sand screen.
13. A method as claimed in claim 12, wherein information from the electromagnetic tool and the device which measures the internal profile of the sand screen is used to create images on a computer screen in three dimensions.
14. A method as claimed in any preceding claim, comprising emitting and detecting alternating magnetic fields/waves.
15. A method as claimed in any preceding claim, comprising emitting electromagnetic waves with a frequency in the range of 5 to 20 Hz.

Patentansprüche

1. Ein Verfahren zum Überwachen der Integrität eines Sandfilters, wobei das Verfahren Folgendes beinhaltet:
 - (a) Leiten mindestens einer elektromagnetischen Welle zu einem Sandfilter innerhalb eines Bohrlochs;
 - (b) Detektieren von mindestens einer reflektierten oder emittierten elektromagnetischen Welle von dem Sandfilter innerhalb des Bohrlochs, um mindestens eine Datenmessung zu produzieren.
2. Verfahren gemäß Anspruch 1, wobei Schritt (a) ein Erfassungsschritt ist.
3. Verfahren gemäß einem der vorhergehenden Ansprüche, wobei es eine Vielzahl von elektromagnetischen Wellen gibt, die in Schritt (a) zu dem Sandfilter geleitet werden, wodurch ein Scan des Sandfilters gebildet wird.
4. Verfahren gemäß einem der vorhergehenden Ansprüche, wobei die Schritte (a) und (b) vorgenommen werden, nachdem das Bohrloch verwendet worden ist, das heißt länger als 1 Tag, optional länger als 6 Monate, oft mehr als 3 Jahre Flüssigkeiten gefördert hat.
5. Verfahren gemäß einem der vorhergehenden Ansprüche, das Folgendes umfasst:
 - (i) Leiten mindestens einer elektromagnetischen Welle zu einem Sandfilter außerhalb eines Bohrlochs unter kontrollierten Bedingungen;
 - und
 - (ii) Detektieren von mindestens einer reflektierten oder emittierten elektromagnetischen Welle von dem Sandfilter in Schritt (i), um mindestens eine Datenmessung zu produzieren.
6. Verfahren gemäß Anspruch 5, wobei die Schritte (i) und (ii) vor den Schritten (a) und (b) durchgeführt werden.
7. Verfahren gemäß Anspruch 5 oder Anspruch 6, wobei der Sandfilter in Schritt (i) und (ii) der gleiche Sandfilter wie der in den Schritten (a) und (b) ist.
8. Verfahren gemäß einem der Ansprüche 5 bis 7, das das Fördern von Flüssigkeit, besonders Kohlenwasserstoffen, aus dem Bohrloch nach Schritt (ii) und vor Schritt (a) beinhaltet.
9. Verfahren gemäß einem der Ansprüche 5 bis 8, wo-

bei das Verfahren ebenfalls Folgendes umfasst:

(c) Datenverarbeitung und Analyse des Vergleichs zwischen den Datenmessungen in Schritt (ii) und Schritt (b).

10. Verfahren gemäß einem der Ansprüche 5 bis 9, wobei ein elektronisches Erfassungswerkzeug in den Schritten (i) und (a) die elektromagnetische Welle zu dem Sandfilter leitet und in den Schritten (ii) und (b) jegliche Reflexion detektiert.
11. Verfahren gemäß Anspruch 10, wobei das Werkzeug mindestens einen Emittier und mehr als 5 Detektoren, optional mehr als zehn Detektoren, beinhaltet.
12. Verfahren gemäß einem der Ansprüche 10 bis 11, wobei das Werkzeug eine Vorrichtung beinhaltet, die das Innenprofil des Sandfilters misst.
13. Verfahren gemäß Anspruch 12, wobei die Informationen von dem elektromagnetischen Werkzeug und der Vorrichtung, die das Innenprofil der Sandfilters misst, verwendet werden, um auf einem Computerbildschirm Bilder in drei Dimensionen zu schaffen.
14. Verfahren gemäß einem der vorhergehenden Ansprüche, das das Emittieren und Detektieren von alternierenden magnetischen Feldern/Wellen beinhaltet.
15. Verfahren gemäß einem der vorhergehenden Ansprüche, das das Emittieren von elektromagnetischen Wellen mit einer Frequenz im Bereich von 5 bis 20 Hz beinhaltet.

Revendications

1. Un procédé pour surveiller l'intégrité d'un tamis à sable, le procédé comprenant :
 - (a) diriger au moins une onde électromagnétique vers un tamis à sable à l'intérieur d'un trou de forage ;
 - (b) détecter au moins une onde électromagnétique réfléchie ou émise à partir dudit tamis à sable à l'intérieur du trou de forage dans le but de produire au moins un relevé de données.
2. Un procédé tel que revendiqué dans la revendication 1, dans lequel l'étape (a) est une étape de diagraphie.
3. Un procédé tel que revendiqué dans l'une ou l'autre revendication précédente, dans lequel une pluralité d'ondes électromagnétiques sont dirigées vers le ta-

mis à sable à l'étape (a), formant ainsi un balayage dudit tamis à sable.

4. Un procédé tel que revendiqué dans n'importe quelle revendication précédente, dans lequel les étapes (a) et (b) sont réalisées après que le trou de sondage a été en utilisation, à savoir, a produit des fluides, pendant plus d'1 jour, facultativement plus de 6 mois, souvent plus de 3 ans. 5
5. Un procédé tel que revendiqué dans n'importe quelle revendication précédente, incluant : 10
 - (i) diriger au moins une onde électromagnétique vers un tamis à sable dans des conditions contrôlées à l'extérieur d'un trou de forage ; 15
 - et
 - (ii) détecter au moins une onde électromagnétique réfléchie ou émise à partir dudit tamis à sable à l'étape (i) dans le but de produire au moins un relevé de données. 20
6. Un procédé tel que revendiqué dans la revendication 5, dans lequel les étapes (i) et (ii) sont menées avant les étapes (a) et (b). 25
7. Un procédé tel que revendiqué dans la revendication 5 ou la revendication 6, dans lequel le tamis à sable à l'étape (i) et à l'étape (ii) est le même tamis à sable que celui des étapes (a) et (b). 30
8. Un procédé tel que revendiqué dans l'une quelconque des revendications 5 à 7, comprenant la production de fluide, en particulier d'hydrocarbures, depuis le trou de sondage après l'étape (ii) et avant l'étape (a). 35
9. Un procédé tel que revendiqué dans l'une quelconque des revendications 5 à 8, le procédé incluant aussi : 40
 - (c) l'analyse et le traitement des données de la comparaison entre les relevés de données à l'étape (ii) et à l'étape (b). 45
10. Un procédé tel que revendiqué dans l'une quelconque des revendications 5 à 9, dans lequel un outil de diagraphie électronique dirige l'onde électromagnétique vers le tamis à sable aux étapes (i) et (a) et détecte toute réflexion aux étapes (ii) et (b). 50
11. Un procédé tel que revendiqué dans la revendication 10, dans lequel l'outil comprend au moins un émetteur et plus de 5 détecteurs, facultativement plus de dix détecteurs. 55
12. Un procédé tel que revendiqué dans l'une quelconque des revendications 10 à 11, dans lequel l'outil

comprend un dispositif qui mesure le profil interne du tamis à sable.

13. Un procédé tel que revendiqué dans la revendication 12, dans lequel des informations provenant de l'outil électromagnétique et du dispositif qui mesure le profil interne du tamis à sable sont utilisées pour créer des images en trois dimensions sur un écran d'ordinateur.
14. Un procédé tel que revendiqué dans n'importe quelle revendication précédente, comprenant l'émission et la détection de champs/d'ondes magnétiques alternatifs.
15. Un procédé tel que revendiqué dans n'importe quelle revendication précédente, comprenant l'émission d'ondes électromagnétiques avec une fréquence dans la gamme allant de 5 à 20 Hz.

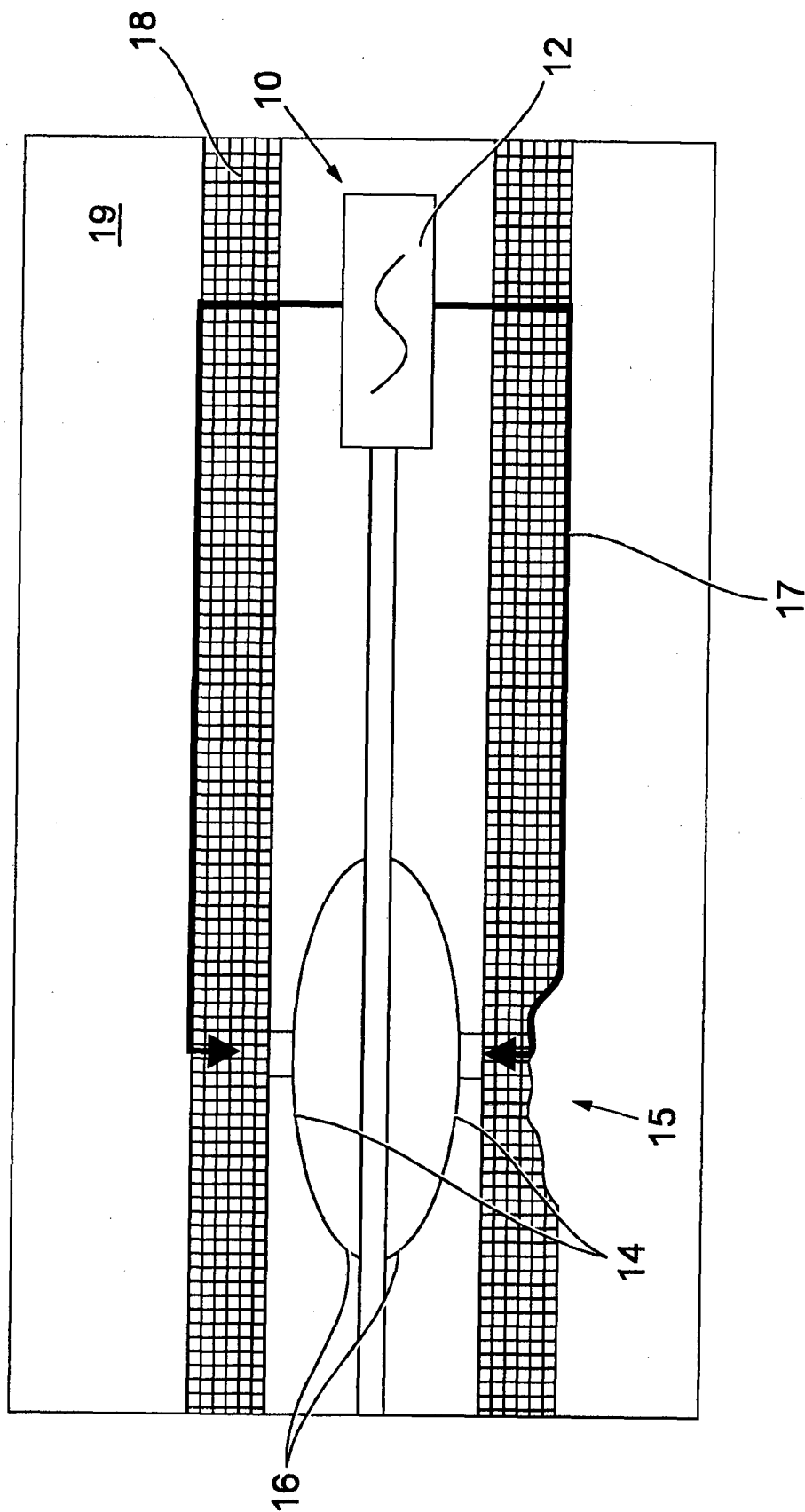


Fig. 1

Fig. 2

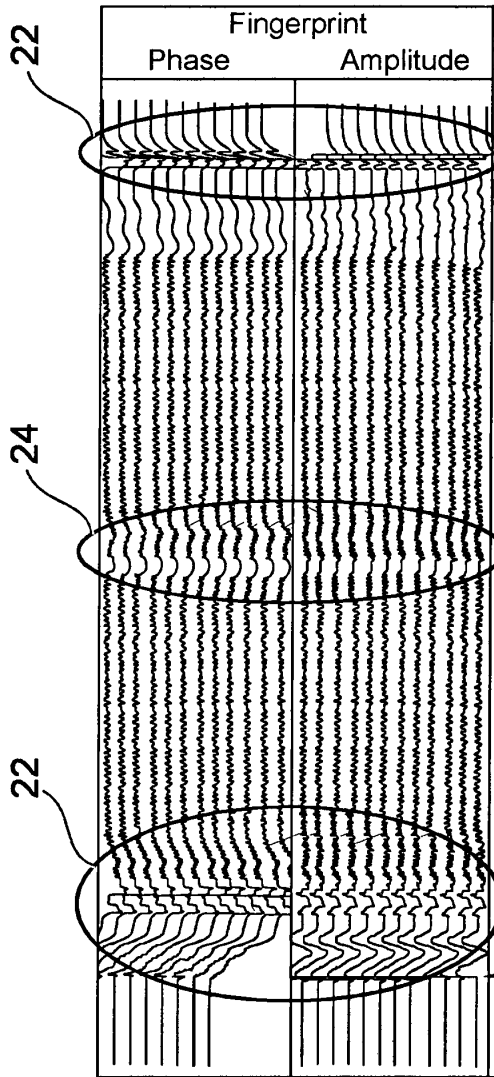


Fig. 3

