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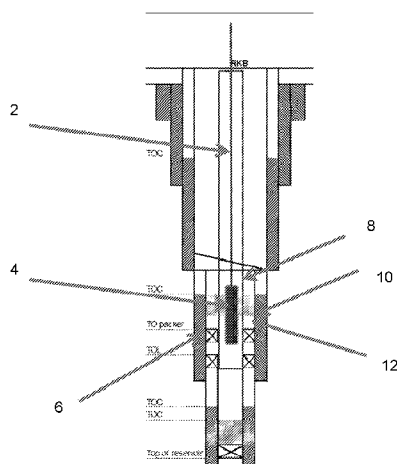


Fig. 1

(57) Abstract: A downhole installation comprises: a first pipe layer 8, a second pipe layer 10 about the first pipe layer, an annulus 12 between the first pipe layer 8 and the second pipe layer 10, and a geological formation outside of the second pipe layer. The downhole installation is evaluated by: using a logging tool 4 within the first pipe layer 8 to obtain data providing azimuthal amplitudes 22 for the third interface echo across a depth interval of interest; calculating a summation or an arithmetic mean 26 for the azimuthal amplitude values 22 at each depth; and using a plot of the summation or arithmetic mean 26 over the logged depth interval as a representation of the characteristics 24 of the material outside of the second pipe layer 10.

EVALUATION OF DOWNHOLE INSTALLATION

The invention relates to a method and an apparatus for evaluation of a downhole installation. The invention may be used to assess the quality of the bond for sealing material formed around a downhole casing in an oil and/or gas installation.

In an oil and/or gas production installation cement, as a sealing material, is cast around a downhole casing for various reasons. Other sealing materials can also be found around a downhole casing, such as shale, barite or collapsed formation material. These materials can fall from the walls about the casing and hence form a packed layer. This can occur with or without an associated cement layer.

A primary role of the cement is to seal the formation's pores, blocking the escape of formation fluids inside the well. The cement provides support to the casing, and also forms a barrier around the casing that, if well-bonded, will prevent fluid migration between different zones of the well. For example, it is desirable to prevent fluid (from all sources) from leaking to the surface outside of the casing. It is also desirable to isolate producing zones from water bearing zones and aquifers. Migration of hydrocarbons into aquifers results in a loss of otherwise valuable hydrocarbons and a risk of environmental damage. Water ingress into producing zones can decrease the value of production and could render a producing zone no longer commercially viable. Proper cement placement between the well casing and the formation is therefore highly important. As a consequence, techniques for evaluating the quality of the cement bond are also highly important.

Barrier layers are expected to have the following properties:

- Impermeability.
- Long term integrity.
- Non-shrinking.
- Ductile - (non brittle) - able to withstand mechanical loads/impact.
- Resistance to chemicals/ substances (H_2S , CO_2 and hydrocarbons).
- Wetting, to ensure bonding to the tube/casing (typically steel).

In newer wells with cemented casings the barrier layer will be relatively new cement and there may be a relatively large amount of information available concerning the make-up and the extent of the barrier layer. In older wells the status of the material behind the casing may be completely unknown. The location of the cement might not be accurately recorded and the cement can be deteriorated. There may also be settled barites, shale, collapsed formation materials and so on, as well as mixtures of those materials.

Cement bond evaluation techniques are used to assess the barrier layers in order to derive qualitative or quantitative data regarding one or more of these properties. Typically it

is required that the cement should be verified via cement bond log with two independent logging measurements/tools being used. Logging measurements should preferably provide azimuthal data enabling identification of 'channelling'. The cement bond log is a representation of the integrity of the cement job, and generally focusses on whether the cement is adhering solidly to the outside of the casing.

The log is typically obtained from one of a variety of sonic-type tools. A relatively basic evaluation technique uses the variations in amplitude of an acoustic signal traveling down the casing wall between a transmitter and receiver to determine the quality of cement bond on the exterior casing wall. The acoustic signal in this case is generated by the transmitter at a low frequency range (for example 8 to 35 kHz). An acoustic mode, for example, extensional or flexural mode, excited in the body of the casing will travel along and inside the body of the pipe and it will be more attenuated in the presence of cement, or other sealing material about the casing, than if the casing were uncemented. This measurement is largely qualitative, as there is no indication of azimuthal cement variations such as channelling, and as it is sensitive to the effect of a microannulus. Newer systems use higher frequency bandwidths, for example 100 to 700KHz or over 1 MHz. These are sometimes called cement evaluation logs or ultrasonic evaluation. They can give detailed, 360-degree representations of the integrity of the cement job.

In the prior art various techniques are described that make use of two basic principles to obtain cement bond logs from tools within the casing. One technique, as described in US 3401773, uses a logging tool with sonic transducers spaced apart along the extent of the casing. A first sonic transducer insonifies the casing with an acoustic wave that propagates along the casing. The characteristics of the wave along the casing are determined by the geometry of the casing and the elastic wave properties of the casing. A refracted wave is received by a second transducer. The received signal can be processed to determine the presence or absence of cement behind the casing by extracting a particular portion of the received signal. If a solid barrier material such as cement is in contact with the outer of the casing then the amplitude of the acoustic wave propagating along the casing is diminished by a relatively small amount and the energy of the extracted portion of the received signal is relatively small. On the other hand, if a liquid is in contact with the casing, indicating an absence of a barrier material or a poor adhesion of the cement leading to a cavity that can be filled by liquid, then the amplitude of the acoustic wave is far less diminished and the extracted portion of the received signal has a correspondingly increased energy. This is a 'shear coupling' type phenomena. The guided mode energy inside the body of the pipe will be affected in terms of relative energy by the shear coupling in the material behind the pipe. There are two types of acoustic body waves, one is called compressional the second is called shear. The two modes exist together as long as the

traveling media is solid, but the shear mode does not travel inside fluid environments (water, muds, air and so on).

This type of technique can therefore provide useful information concerning the presence or absence of the barrier material adjacent to an interface between the casing and the annulus. However, it is not sensitive to the size of the void between the barrier material and the casing, and may hence in some cases indicate that there is no barrier material when a material such as cement is present and there is a small spacing between the cement and the casing. Such a 'microannulus' can be acceptable as cement lining with a microannulus may still provide a hydraulic barrier, and therefore it is an advantage to be able to identify an acceptable microannulus as distinct from a larger, unacceptable, spacing.

In another known prior art technique, as described for example in US 2538114 and US 4255798, an ultrasonic pulse echo technique is used, whereby a single transducer mounted on a logging tool within the casing is used to insonify the casing at near normal incidence and receives reflected acoustic information. With this arrangement the transducer insonifies the casing in such a way as to prompt resonance across the thickness of the casing. A portion of the acoustic wave is transferred into the casing and reverberates between a first interface at the junction of fluid within the casing and the casing material, and a second interface formed between the casing and the annulus behind the casing. The level of energy loss for this acoustic wave at each reflection changes depending on the nature of the matter (e.g. cement or fluid) behind the casing. It is suggested that this technique can more accurately discriminate different cement bond conditions including identification of acceptable microannuli.

A further prior art technique makes use of angled transducers as shown in US 6483777. The angle of the transducer is set to be larger than a shear wave critical angle of the interface between the fluid within the casing and the material of the casing. The transducer therefore excites a flexural wave in the casing by insonifying the casing with an excitation at an angle greater than the shear wave critical angle. This flexural wave propagates along within the casing and sheds energy to the fluid inside the casing and to the material behind the casing. The flexural wave is a shear wave which propagates well in the solid material of the casing, but does not propagate in fluid due to the different molecular conditions. A portion of the flexural wave energy is leaked outside of the casing in the form of a compressional wave, which can propagate within solid or fluid in the annulus of the material outside of the casing. This wave may be refracted or reflected at a third interface, which in US 6483777 is an outer boundary of the annulus. An echo is generated at the third interface (the third interface echo, third interface echo) and consequently this method provides additional data concerning the material within the annulus. As a portion of the flexural wave energy leaks into the annulus and reflects/refracts back to the receiver on the

tool then this method can obtain data providing information about the entirety of the matter within the annulus, i.e. over an entire distance separating the casing and the third interface. Essentially, it has been shown that the casing is made “transparent” allowing the logging tool to “see” beyond the casing to the material of the annulus.

5 EP 1505252 describes yet a further prior art logging tool. In this example the logging tool has a plurality of acoustic transducers including a transducer for insonifying the casing with an acoustic wave at an angle, a transducer for insonifying the casing with a wave at normal incidence, and a pair of transducers operated at an angle to receive reflected and refracted waves from the casing as well as from the third interface. The transducers are at
10 different positions along the length of the casing. The device thus includes a flexural transmitting transducer, a pulse echo transducer and two transducers for receiving acoustics generated by the flexural wave, being a near flexural receiving transducer and a far flexural receiving transducer. This technique allows for a greater amount of information to be derived concerning the material in the annulus behind the casing.

15 An example of the type of tool described in EP 1505252 that can be obtained commercially is an IBC Isolation Scanner as provided by Schlumberger Limited. The use of this tool has been well developed by the industry.

However, there remain issues to address in relation to determination of conditions within a downhole installation, in particular when seeking to measure the condition of the
20 cement, or other material within the annulus about the casing, when there is a sequence of concentric pipes, for example when a tubing has been installed within the casing. Current well integrity logging using ultrasonic and acoustic methods requires logging operations to be performed into a single layered pipe (i.e. target sealing material placed behind one casing wall) and not in dual casing or multiple casing environments.

25 Viewed from a first aspect, the present invention provides a method of evaluation of a downhole installation, wherein the downhole installation comprises: a first pipe layer, a second pipe layer about the first pipe layer, an annulus between the first pipe layer and the second pipe layer, and a geological formation outside of the second pipe layer, the method comprising: using a logging tool within the first pipe layer in order to obtain data providing
30 azimuthal amplitudes for the third interface echo across a depth interval of interest; calculating a summation or an arithmetic mean for the azimuthal amplitude values at each depth; and using a plot of the summation or arithmetic mean over the logged depth interval as a representation of characteristics of the material outside of the second pipe layer.

35 With this method, third interface echo data obtained from within a first pipe layer can provide information about the material outside of a second pipe layer. It has been found that the third interface echo, in the case of a two pipe layer system, is not necessarily a reflection as has been previously suggested. Instead it may be considered to be energy arising due to

a headwave generated by a flexural wave inside the second pipe. As used herein, the term third interface echo denotes the third 'echo' (the third peak in amplitude received by a receiver) which appears as being received from a third interface counting from the source outward towards the formation. In the two pipe system of the first aspect, the first interface is the inside face of the first pipe layer, the second interface is the external face of the first pipe layer, the third interface is the internal face of the second pipe layer, the fourth interface is the external face of the second pipe layer, and the fifth interface is a subsequent formation boundary or possibly the internal face of a subsequent casing/pipe layer.

One reason for the use of the flexural wave is for light cements and foam cement evaluation. Those particular cements are used in complex wells, such as ultradeep high pressure and high temperature wells, because they are much stable. They have impedance characteristics below 3.9 MRayl, which is recognized as a critical impedance. The conventional vertical incidence ultrasonic will generate an extensional mode (balloon, A0) in the body of the pipe. This is an asymmetric mode of vibration. The impedance characteristics of the contact between the pipe and sealing material will be affected in terms of relative values and the light cement may look like fluids because there is not enough shear coupling.

By exciting shear mode/flexural or zeroth symmetric mode in the body of the pipe (like a belt vibration, S0), then there is a shear to pressure conversion in the material behind the pipe, so we are confident that attenuation of the shear is dictated by the pressure coupling and not shear coupling. The excitation of S0 (zeroth symmetric mode or flexural) in the first pipe layer enables the first pipe layer to act as a source of pressure/compressional waves (P waves). While the S0 travels along the body of the pipe it will continually "leak P" on both sides of the pipe.

In one example method, where the first pipe layer is a tubing within a second pipe layer in the form of a casing, then the third interface echo data can be used to determine information about the material outside of the casing. The material in the annulus outside of the casing could be downhole fluids such as hydrocarbons, water, sand or mud, and of particular interest it would typically include a cement lining at given depths. The proposed method may hence be used to obtain cement bond log (CBL) data for a casing, by means of data obtained through a tubing within the casing. Thus, the method may be a method of cement bond evaluation for a downhole installation and the representation of the characteristics of the material outside of the second pipe layer may be a representation of the cement bond log. It has been found that the magnitude of the summed or averaged third interface echo amplitudes provides a trend that follows the trend of a single pipe CBL for the same casing/pipe layer. It is a significant advantage to be able to obtain CBL data (and

similar data) in this way, without the need to remove the first pipe layer (the tubing, for example) from the second pipe layer (the casing, for example).

The summed third interface echo amplitudes can be used when the same number of azimuthal amplitudes is obtained at each depth, since of course this will be directly proportional to the arithmetic mean and hence will show the same trends. The arithmetic mean may be used when the same or a different number of azimuthal amplitudes are obtained, and it is recommended to use the mean in case there are different numbers of azimuthal amplitudes, which is common for some logging tools.

The method may include deploying the tool within the first pipe layer, and this may be done via any suitable technique, for example via wireline or via a logging whilst drilling (LWD) system.

Numerical values of azimuthal amplitudes for the third interface echo may be extracted from the data provided by the logging tool by suitable processing steps, which may of course change depending on the tool that is used.

The logging tool should be capable of obtaining third interface echo data and therefore it will typically include a transmitter (or transducer) for exciting a flexural wave in the first pipe layer and thereby create the required leakage into the annulus between the first pipe layer and the second pipe layer. One possible tool includes an angled transmitter for insonifying a flexural wave in the first pipe layer, along with a near flexural receiver and a far flexural receiver for receiving reflected and/or refracted waves generated by the flexural wave. The near and far flexural receivers may be angled receivers spaced apart from the transmitter by different distances in the depth direction of the pipe layers, that is to say, the near and far receivers are spaced from the transmitter along the axis of the tool that is, in use, aligned with the depth direction of the pipe layers. As is known, the transmitters and receivers may be transducers. Also as is known, the tool may be arranged to rotate within the first pipe layer to thereby obtain multiple sets of readings at differing azimuthal angles for each depth. Optionally the tool may include a pulse echo transducer arranged to insonify the first pipe layer with near normal incidence. This can enable the tool to obtain additional data concerning the annulus between the first pipe layer and the second pipe layer.

The method may advantageously be used to assess the quality of the bond for cement formed around a downhole casing in an oil and/or gas installation.

It will be appreciated that the steps relating to processing of the data may be carried out at a different time and in a different place to the steps concerning obtaining the data using the logging tool.

The method may be implemented by means of computer software for processing data obtained by a suitable logging tool. Thus, the invention extends in a further aspect to a computer programme product comprising instructions that, when executed, will configure a

computer apparatus to implement a method comprising: receiving data providing azimuthal amplitudes for the third interface echo across a depth interval of interest in a downhole installation that comprises: a first pipe layer, a second pipe layer about the first pipe layer, an annulus between the first pipe layer and the second pipe layer, and a geological formation outside of the second pipe layer; calculating a summation or an arithmetic mean for the azimuthal amplitude values at each depth; and using a plot of the summation or arithmetic mean over the logged depth interval as a representation of characteristics of the material outside of the second pipe layer.

The method implemented by the computer programme product may include any or all features as described above in relation to the method of the first aspect and its preferred features. The method may be a method of cement bond evaluation for a downhole installation and the representation of the characteristics of the material outside of the second pipe layer may be a representation of the cement bond log for the second pipe layer, which may be a casing. The method may include determining numerical values of azimuthal amplitudes for the third interface echo from the received data.

In a yet further aspect, the invention also provides a system for evaluation of a downhole installation, wherein the downhole installation comprises: a first pipe layer, a second pipe layer about the first pipe layer, an annulus between the first pipe layer and the second pipe layer, and a geological formation outside of the second pipe layer, the system comprising: a logging tool for deployment within the first pipe layer in order to obtain data providing azimuthal amplitudes for the third interface echo across a depth interval of interest; and a processor arranged to: calculate a summation or an arithmetic mean for the azimuthal amplitude values at each depth and use a plot of the summation or arithmetic mean over the logged depth interval as a representation of characteristics of the material outside of the second pipe layer.

The invention extends to a downhole installation equipped with the system. The system may be a cement bond evaluation system for a downhole installation and the representation of the characteristics of the material outside of the second pipe layer may be a representation of the cement bond log. In one example, the first pipe layer is a tubing within a second pipe layer in the form of a casing and the third interface echo data is used to determine information about the material outside of the casing.

The processor of the system may be arranged to perform any or all steps described above in relation to the method of the first aspect. The processor may be located onboard the logging tool, or it may be located remotely, for example it may be a processor above ground close to or remote from the downhole installation/logging tool.

The logging tool may be arranged for deployment within the first pipe layer via wireline or via a logging whilst drilling (LWD) system.

In some example embodiments, the logging tool includes a transmitter for exciting a flexural wave in the first pipe layer and thereby creating the required leakage into the annulus between the first pipe layer and the second pipe layer for obtaining the third interface echo. One possible tool includes an angled transmitter for insonifying a flexural wave in the first pipe layer, along with a near flexural receiver and a far flexural receiver for receiving reflected and/or refracted waves generated by the flexural wave. As is known, the transmitters and receivers may be transducers. Also as is known, the tool may be arranged to rotate within the first pipe layer to thereby obtain multiple sets of readings at differing azimuthal angles for each depth. Optionally the tool may include a pulse echo transducer arranged to insonify the first pipe layer with near normal incidence. This can enable the tool to obtain additional data concerning the annulus between the first pipe layer and the second pipe layer. The tool could for example be similar to that described in EP 1505252.

Certain preferred embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 shows a casing bond logging recording system in situ within a tubing;
Figure 2 illustrates details of the wireline logging tool in Figure 1;
Figure 3 shows an amplitude map for the third interface echo; and
Figure 4 illustrates a mean of azimuthal amplitudes of the third interface echo determined as proposed by the inventor.

A typical downhole installation is shown schematically in Figure 1. The borehole extends from surface level down to a reservoir. Fluid is extracted from the reservoir through downhole tubing 8. The tubing 8 is held within a casing 10. An annulus 12 is formed between the tubing 8 and the casing 10. There is also another annulus 6 formed between the outside of the casing 10 and the formation, or optionally between the outside of the casing 10 and yet further casings. In this example we consider the simplest case of a tubing 8 within a casing 10. The interior of the tubing 8 and the annulus 12 between tubing 8 and casing 10 are filled with fluid, typically in the liquid phase. The annulus 6 between casing 10 and the formation may be filled with any type of material, such as cements, barite, drilling fluids and so on.

A wireline logging tool 4 is deployed inside the tubing. It is supported from above via a wireline logging cable 2. It will be appreciated that the logging tool 4 could also be deployed via a "logging while drilling" (LWD) system. The wireline logging tool 4 is shown in Figure 2 in schematic form. The tool 4 is arranged for rotation about the vertical axis of the borehole as shown by the arrow at the base of the Figure. In its most basic form a suitable tool includes an angled transmitter transducer 20 for insonifying a flexural wave, a pulse echo transducer 18, a near flexural receiver transducer 16 and a far flexural receiver transducer 14. Thus, it will be understood that this tool could be broadly similar in terms of its

structural features to the tool described in EP 1505252. The basic operation of the tool is already known, and could again be as described in this prior art reference, and therefore it will not be set forth in detail herein. The inventor proposes a new use of this type of tool, and similar tools, in order to evaluate the cement bond quality about a casing when the tool is located within a tubing inside the casing. This provides a significant advance compared to known systems, since it means that the cement bond log can be obtained more cheaply and more easily.

It is accepted by industry that a third interface echo (TIE) can be obtained via a tool of the type shown in Figure 2. Various prior art has shown the use of this phenomenon to obtain data about the material in an annulus outside of a casing, when the tool is within the casing. As explained above, it is believed that the third interface echo is not purely an echo as such and therefore it becomes possible to draw new conclusions about the second pipe layer, and the surrounding material.

In the current proposal, as shown in Figure 1, the tool may be within a tubing 8 that is itself within a casing 10. Here, it is desirable to be able to obtain information about the material in the annulus, and in particular to obtain cement bond logging information, by use of the tool to "see" through both of the tubing 8 and the casing 10.

The amplitude of the third interface echo can be measured and displayed as shown in Figure 3. It has surprisingly been found that this data can be processed to provide a basic cement bond log (CBL) measurement for a cement lining behind the casing, i.e. information about the material behind the second layer of piping. The proposed method is as follows.

Step 1. Deploy the tool inside tubing and log the entire interest interval.

Step 2. Isolate numerical values of azimuthal amplitudes for the third interface echo.

Step 3. Execute a summation of all azimuthal amplitude values.

Step 4. Calculate the arithmetic mean of the third interface echo amplitudes values.

Step 5. Display this arithmetic mean over entire logging interval to provide a representation of CBL for the annulus behind the second layer.

Thus, it has been found that the trend (shape) of the arithmetical mean of the sum of all azimuthal amplitudes of the third interface echo recorded with the tool inside the tubing 8, over depth intervals, will be similar to the standard CBL trend (shape) in the outer casing 10, after removing the tubing 8. It will be understood that the same principle might be applied to obtain information about other annulus materials and properties, even with more than two layers of pipes: the basic principle is the same, since the mean of summed azimuthal amplitudes for the third interface echo will always provide a representation of the interface between the pipe layer concerned (in this example the casing 10) and the material outside that layer (in this example the material of the annulus 6, between the casing 10 and the formation).

An example is shown in Figure 4. This Figure shows the trend (shape) of the average of the sum of all azimuthal amplitudes of third interface echo over depth intervals along with a corresponding standard CBL trend (shape) in single casing. The data is shown in two columns, which have the same general content. At the left of each column a panel 22 shows the azimuthal amplitude map of third interface echo for the second pipe. Then, viewing left to right, there is a panel 24 showing a single pipe CBL, followed by a panel 26 showing all azimuthal amplitudes summed and then averaged.

The shape of the average of summed azimuthal amplitudes 26 can be compared with the shape of the single pipe CBL 24. These shapes are overlaid in the next panel 28, with the darker shaded area indicating where there is a match between the single casing CBL 24 and the double casing average amplitudes 26. The final two panels show a datum 30 that is similar to the double casing average amplitudes 26 but shown over an alternative scale and on the far right hand side there is a representation of the difference 32 between the single CBL 24 and the double casing average amplitudes 26. It will be seen that in many parts of the pipe there is a minimal difference, indicating a high degree of accuracy when the double casing average amplitudes 26 are used as an approximation of the single CBL 24.

It will be observed that shape for the average third interface echo amplitudes 26 recorded inside the tubing 8 are a reasonable match, in terms of the shape to the single pipe CBL measurement 24 for the casing. It should be understood that the numerical values are not of significance. Instead the important feature is the correspondence of the shape and trend of the curves. Deflections to the right on the average third interface echo amplitudes 26 correspond with deflections to the right on the single pipe CBL 24. Consequently, the third interface echo data obtained from within the tubing 8 can be used to provide a representation of the CBL data that would have been obtained for a single pipe, i.e. for the casing 10 with the tubing removed. Since the numerical values, i.e. the magnitude of the figure from the third interface echo data, is not significant then the arithmetic mean could be replaced with a summation, assuming that at each depth the same number of azimuthal amplitudes is measured.

It will be seen that there is a better match of the two curves for highly bonded intervals and where mismatches occur then this is in possible debonded areas. The proposed method therefore does not show a false positive and hence it fails safe. The method provides a simple, cheap and robust way to obtain information about possible debonded areas (and other similar phenomena).

It should be noted that that the eccentricization of the tubing 8 or the presence of debris in the annulus between the tubing 8 and casing 10 may affect the measurements in the sense that the amplitudes may become smaller due to acoustic dispersive media and miss

capture of the third interface echo due to high eccentricization effects. However, even if these effects are present the general trend and shape of the casing CBL can be evaluated.

CLAIMS:

1. A method of evaluation of a downhole installation, wherein the downhole installation comprises: a first pipe layer, a second pipe layer about the first pipe layer, an annulus between the first pipe layer and the second pipe layer, and a geological formation outside of the second pipe layer, the method comprising:
- 5 using a logging tool within the first pipe layer in order to obtain data providing azimuthal amplitudes for the third interface echo across a depth interval of interest;
- calculating a summation or an arithmetic mean for the azimuthal amplitude values at
- 10 each depth; and
- using a plot of the summation or arithmetic mean over the logged depth interval as a representation of characteristics of the material outside of the second pipe layer.
2. A method as claimed in claim 1, being a method of cement bond evaluation
- 15 for a downhole installation wherein the representation of the characteristics of the material outside of the second pipe layer is a representation of the cement bond log.
3. A method as claimed in claim 1 or claim 2, wherein the first pipe layer is a tubing within a second pipe layer in the form of a casing, and wherein the third interface
- 20 echo data is used to determine information about the material outside of the casing.
4. A method as claimed in claim 1, 2 or 3, wherein the logging tool includes a transmitter for exciting a flexural wave in the first pipe layer.
5. A method as claimed in claim 4, wherein the logging tool includes an angled
- 25 transmitter for insonifying the flexural wave along with a near flexural receiver and a far flexural receiver, the near and far flexural receivers being angled receivers spaced apart from the transmitter by different distances along the tool in the depth direction.
6. A method as claimed in any preceding claim being used to evaluate a
- 30 downhole casing in an oil and/or gas installation.
7. A computer programme product comprising instructions that, when executed, will configure a computer apparatus to implement a method comprising:
- 35 receiving data providing azimuthal amplitudes for the third interface echo across a depth interval of interest in a downhole installation that comprises: a first pipe layer, a

second pipe layer about the first pipe layer, an annulus between the first pipe layer and the second pipe layer, and a geological formation outside of the second pipe layer;

calculating a summation or an arithmetic mean for the azimuthal amplitude values at each depth; and

5 using a plot of the summation or arithmetic mean over the logged depth interval as a representation of characteristics of the material outside of the second pipe layer.

8. A computer programme product as claimed in claim 7 wherein the method is as claimed in any of claims 1 to 6.

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9. A system for cement bond evaluation for a downhole installation, wherein the downhole installation comprises: a first pipe layer, a second pipe layer about the first pipe layer, an annulus between the first pipe layer and the second pipe layer, and a geological formation outside of the second pipe layer, the system comprising:

15 a logging tool for deployment within the first pipe layer in order to obtain data providing azimuthal amplitudes for the third interface echo across a depth interval of interest; and

a processor arranged to: calculate a summation or an arithmetic mean for the azimuthal amplitude values at each depth and use a plot of the summation or arithmetic mean over the logged depth interval as a representation of characteristics of the material outside of the second pipe layer.

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10. A system as claimed in claim 9, wherein the logging tool includes a transmitter for exciting a flexural wave in the first pipe layer.

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11. A system as claimed in claim 10, wherein the logging tool includes an angled transmitter for insonifying the flexural wave along with a near flexural receiver and a far flexural receiver, the near and far flexural receivers being angled receivers spaced apart from the transmitter by different distances along the tool in the depth direction.

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12. A system as claimed in claim 9, 10 or 11, wherein the processor is be arranged to perform the method steps of any of claims 1 to 6.

13. A downhole installation equipped with the system of any of claims 9 to 12.

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14. A downhole installation as claimed in claim 13, wherein the first pipe layer is a tubing within a second pipe layer in the form of a casing and the third interface echo data is used to determine information about the material outside of the casing.

5 15. A method, a computer programme product, a system or a downhole installation substantially as hereinbefore described with reference to the accompanying drawings.

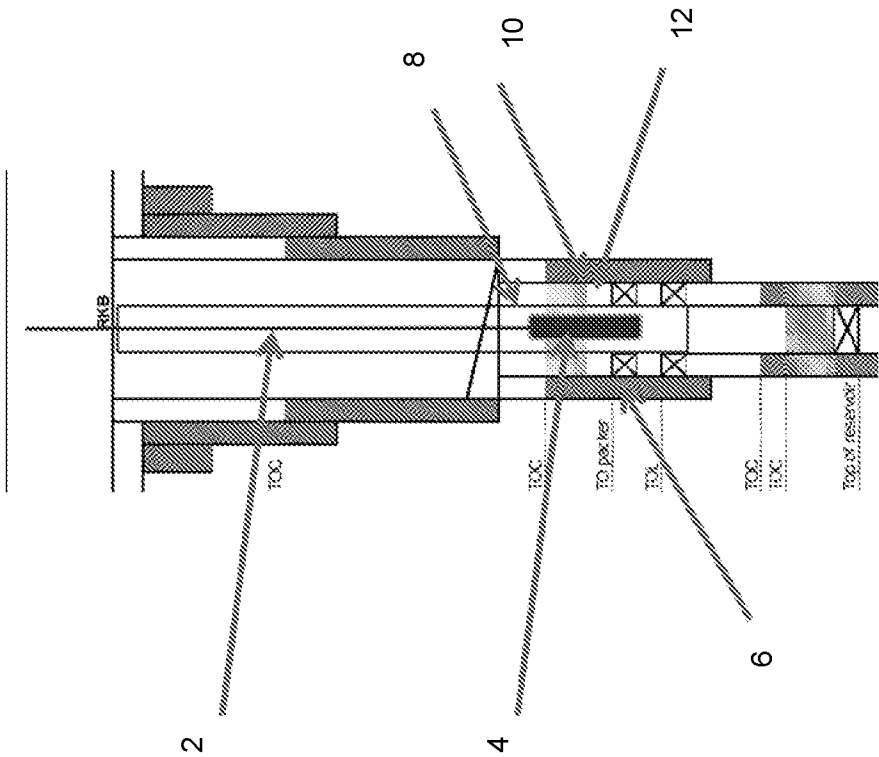


Fig. 1

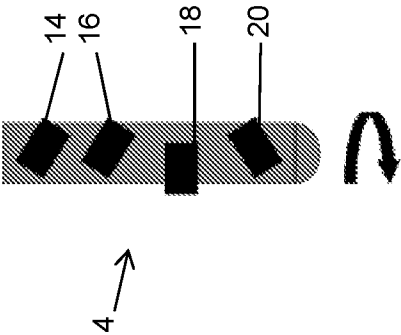


Fig. 2

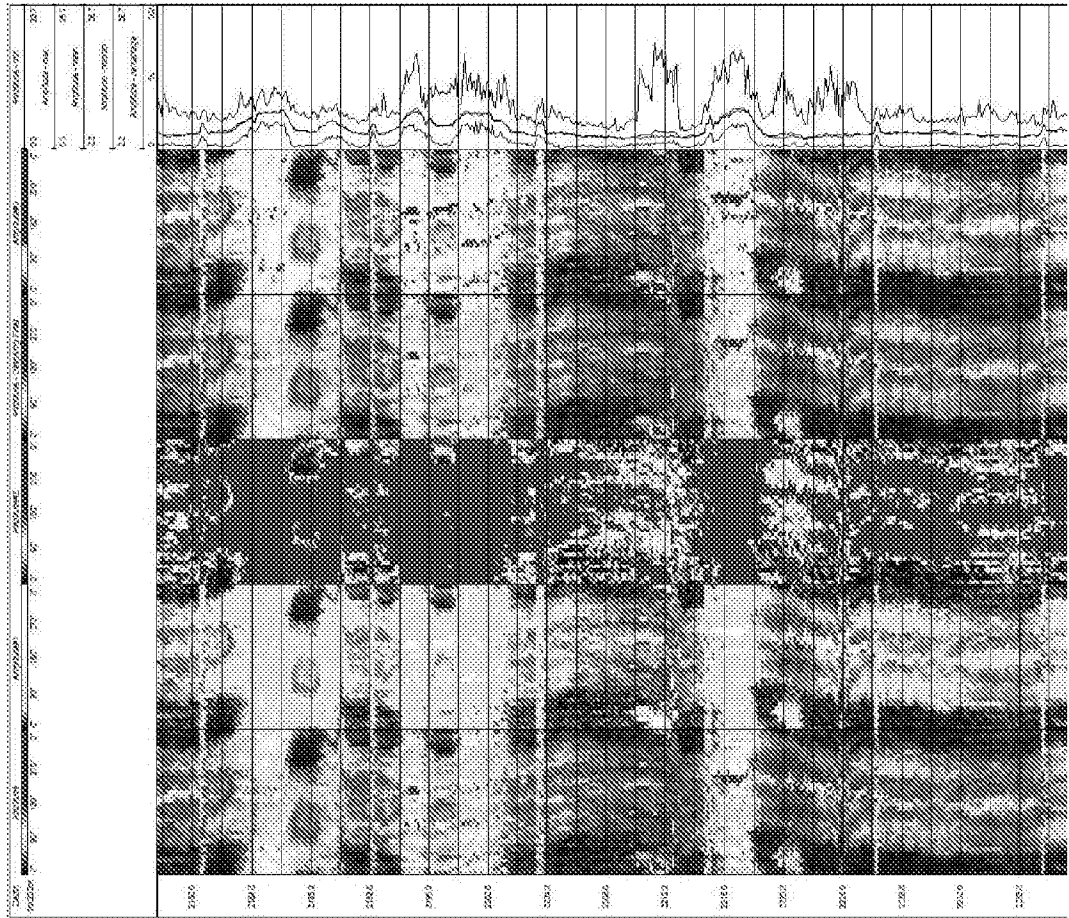


Fig. 3

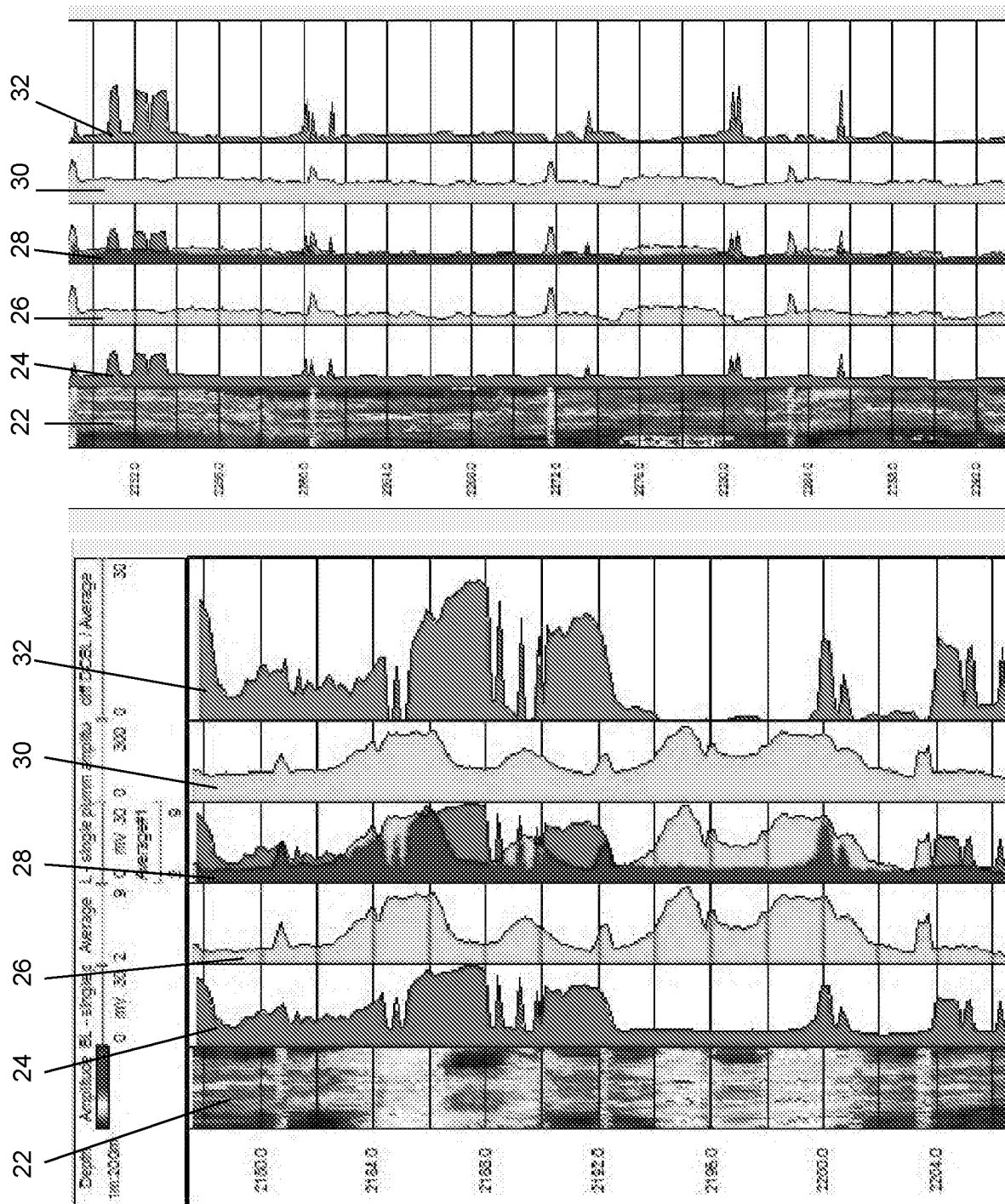


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2015/050255

A. CLASSIFICATION OF SUBJECT MATTER E21B 47/005 (2012.01), G01V 1/50 (2006.01), G01V 1/44 (2006.01) According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC: E21B, G01V Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched DK, NO, SE, FI: Classes as above. Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPODOC, WPI		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	TIMONIN, A. et al. "Microannulus and Cement Evaluation: Effectiveness of Cement Evaluation Using Sonic and Ultrasonic Technologies in Wells with Microannulus Between Casing and Cement Sheath" SPE Annual Caspian Technical Conference and Exhibition, 12-14 Nov 2014, Astana, Kazakhstan. SPE 172309. Abstract, page 3 lines 13-27, page 11 lines 28-33, figs. 3, 10.	1-14
A	WO 2014/139593 A1 (STATOIL PETROLEUM AS) 2014.09.18 Page 3 lines 9-17, page 5 line 12-page 7 line 5, fig. 1.	1-14
A	VAN KUIJK, R. et al. "A Novel Ultrasonic Cased-Hole Imager for Enhanced Cement Evaluation." International Petroleum Technology Conference, 21-23 Nov 2005, Doha, Qatar. IPTC 10546. Abstract, page 4 col. 1 line 1-page 7 col. 1 line 23, figs. 4, 5, 7, 9, 10.	1-14
A	ZEROUG, S. et al. "Ultrasonic Leaky-Lamb Wave Imaging Through A Highly Contrasting Layer", 2003, PROCEEDINGS IEEE ULTRASONICS SYMPOSIUM, vol. 1, p. 794-798. Whole document.	1-14
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
21/03/2016		22/03/2016
Name and mailing address of the ISA Nordic Patent Institute Helgeshøj Allé 81 DK - 2630 Taastrup, Denmark. Facsimile No. + 45 43 50 80 08		Authorized officer Kalland, Bjørn Inge Telephone No. +47 22 38 74 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2015/050255

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:

because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claim No.: 15

because it relates to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

Claim 15 lacks clarity as it refers to multiple claim categories and relies on general references to the description and drawings only. Hence, the claim cannot be given a definite construction, and a meaningful international search cannot be carried out.

3. ☐ Claims Nos.:

because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2015/050255

Patent document cited in search report / Publication date		Patent family member(s) / Publication date	
WO 2014139593 A1	2014.09.18	NO 20151218 A	2015.09.17
		US 2016041287 A1	2016.02.11