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(54) Abstract Title: **Downhole power generation using fluid flow and a turbine**

(57) A downhole electrical power generation apparatus includes first and second fluid receiving chambers 21a, 21b. A fluid communication path 24a is present between the chambers and a turbine generator 26 is disposed so that fluid flowing from the first chamber 21a to the second chamber 21b operates the turbine generator 26 to generate electrical power. Stored pressurised gas and/or ambient downhole pressure may be used to force the fluid between the chambers 21a, 21b.

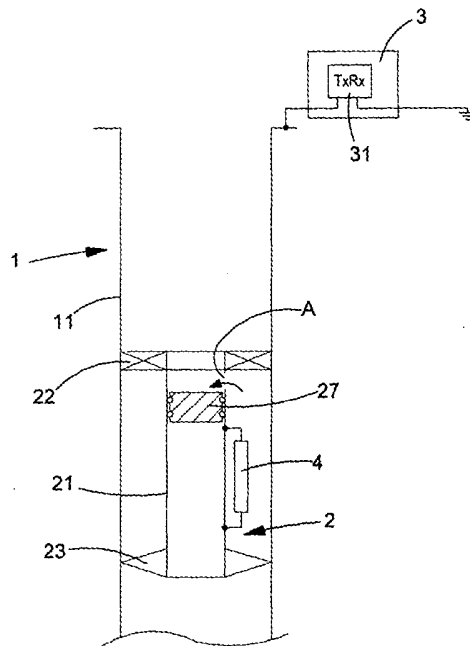


FIG.1

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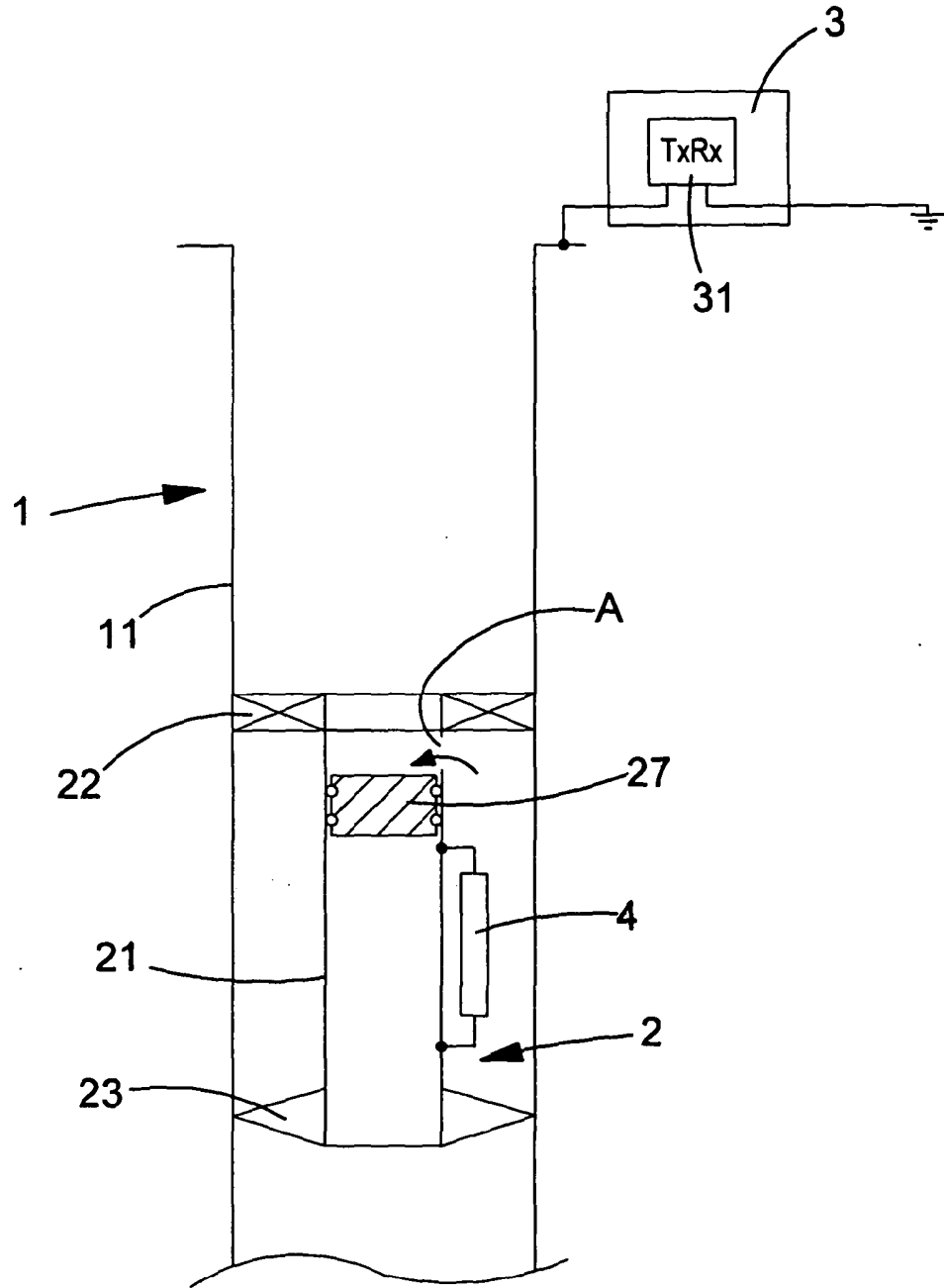


FIG.1

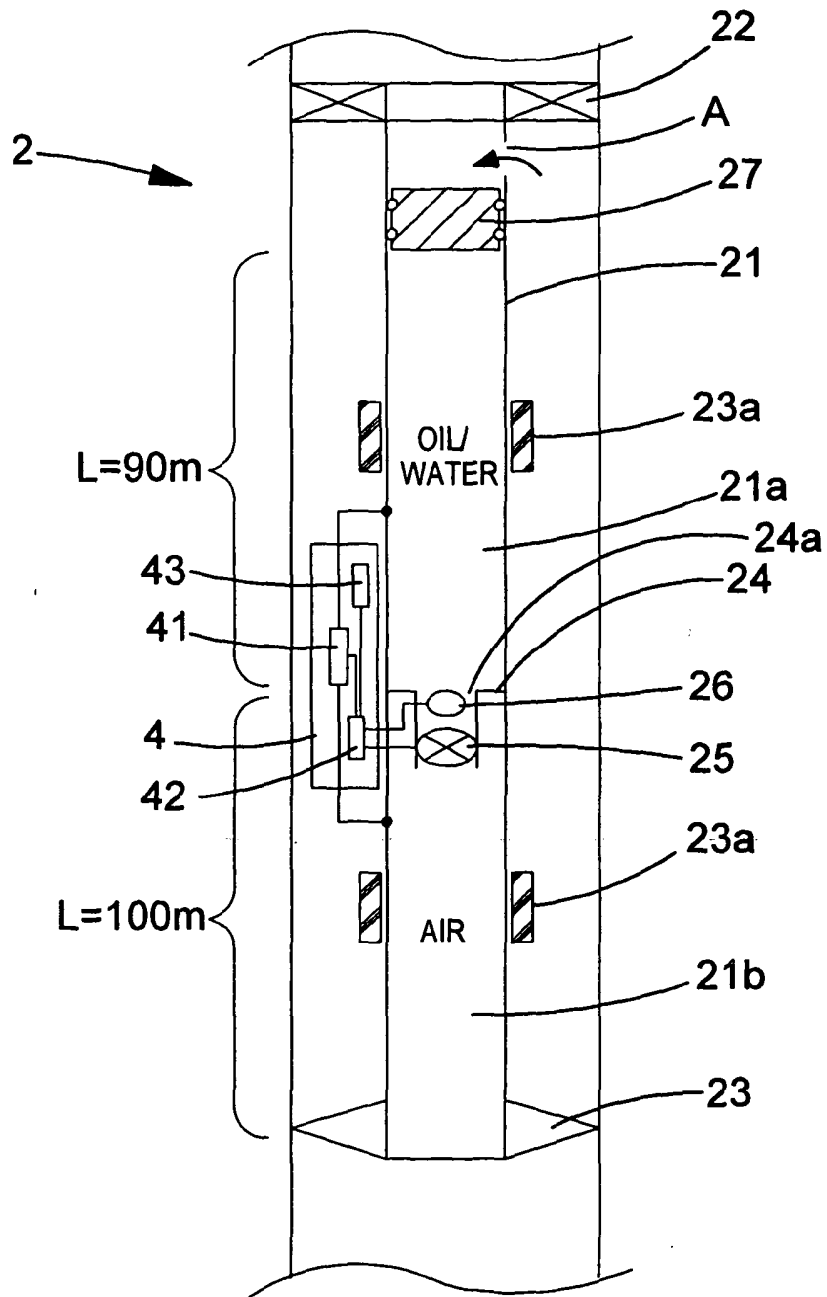


FIG.2

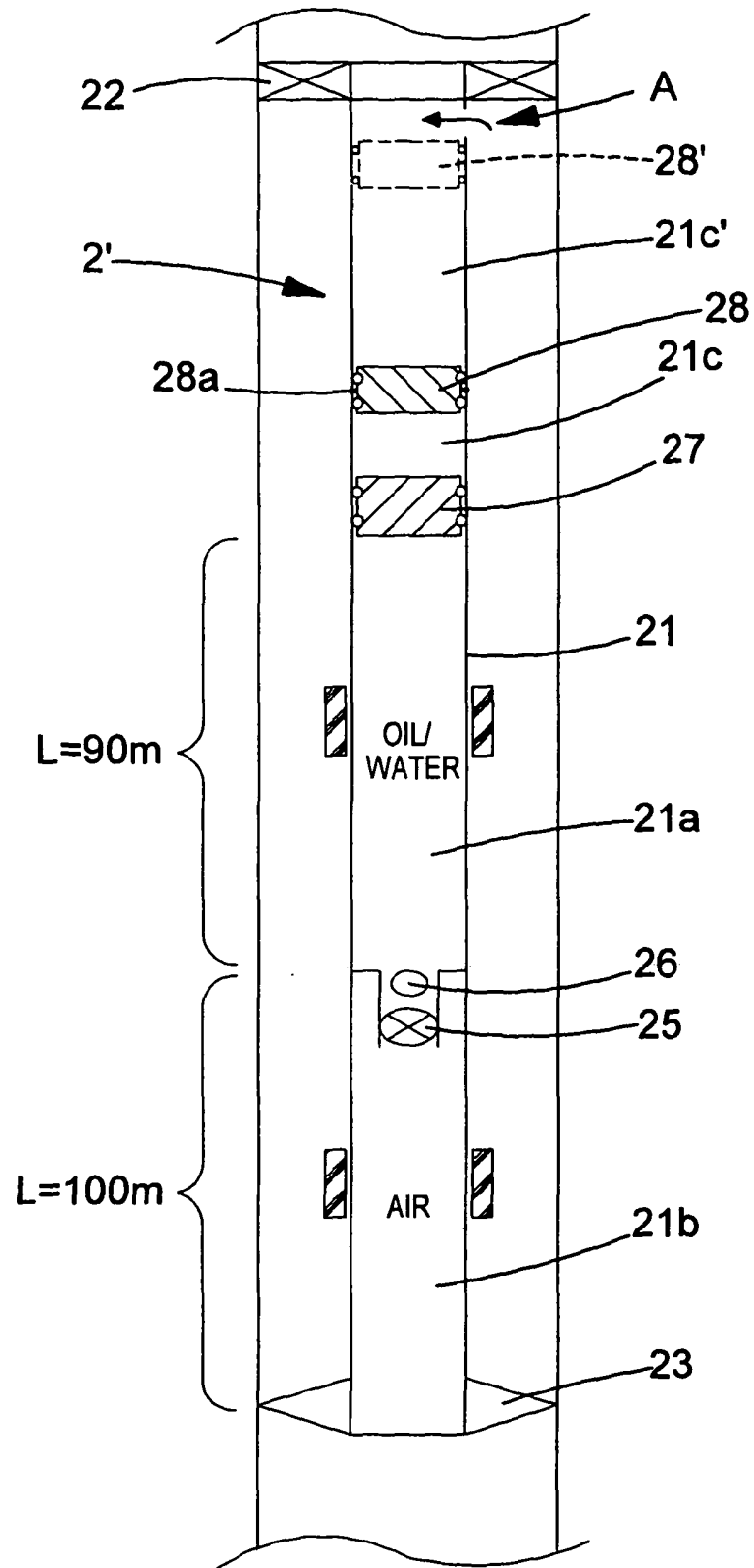


FIG.3

DOWNHOLE POWER GENERATION

This invention relates to downhole electrical power generation.

5 There are a number of situations where it is desirable to have equipment downhole in an oil or gas well which requires power to operate. In many circumstances electrical power is necessary or preferred. Thus, for example, sensors are often provided downhole for measuring parameters such as pressure and/or temperature. The power requirements for such measurements may be low, but it can be a different matter when
10 it comes to sending data relating to those measurements back to the surface.

One communication technique which is now used by the Applicants, amongst others, makes use of the metallic structure of the well itself, that is to say the metallic tubing provided in the well, (e.g. casing, liner or production tubing), as a signal channel for
15 carrying electrical signals between the surface and the downhole location. Such signalling can be made to work well using very low frequency and very high current signals. Often the data rates achievable are not particularly high, but this does not matter where relatively little data needs to be transmitted – for example, pressure readings taken say, once a day or even less frequently. However, because of losses,
20 the power required to transmit the data can be high and this can lead to a large quantity of expensive batteries being required to transmit many readings from a downhole tool. Furthermore, there is a problem in that batteries tend to self-discharge, particularly in the high temperatures which are normal downhole. Thus, even when readings are not being transmitted to the surface, power from the batteries
25 can be lost just as time elapses.

Thus, it is an aim of the present invention to provide an alternative downhole power source.

According to one aspect of the present invention there is provided downhole electrical power generation apparatus comprising first and second fluid receiving chambers, a fluid communication path for allowing flow of fluid from the first chamber via the fluid communication path to the second chamber and a turbine generator disposed so that fluid flowing from the first chamber via the fluid communication path to the second chamber operates the turbine generator to generate electrical power.

10

The second chamber may be sealed against the ingress of fluid except for fluid received from the first chamber. The second chamber may be sealed against the ingress of fluid except via the fluid communication path from the first chamber.

15 The first chamber may be sealed against the egress of fluid except for fluid supplied towards the second chamber. The first chamber may be sealed against the egress of fluid except via the fluid communication path to the second chamber.

20 The first chamber may be arranged to receive a liquid. The second chamber may be arranged to receive a gas. The first chamber may hold a liquid, for example oil or water. The second chamber may hold a gas, for example air.

The power generation apparatus may comprise a piston which is moveable to reduce the volume of the first chamber for driving fluid from the first chamber into the second chamber.

25

The piston may be moveable under action of ambient pressure.

The power generation apparatus may comprise pressure transfer means for
5 transferring ambient pressure in the region in which the apparatus is disposed to fluid
held in the first fluid receiving portion.

The power generation apparatus may comprise a portion of tubing which partly
defines the first chamber and the second chamber. The portion of tubing may have a
10 blanked end which defines one end of the second chamber. The piston may be
provided in and seal with the tubing to define one end of the first chamber. The
piston may be arranged to slide axially relative to the tubing to alter the volume of the
first chamber.

15 The power generation apparatus may comprise a third fluid receiving chamber, which
may be arranged to be pressurised using ambient pressure. The third chamber may
hold a gas, for example air.

The power generation apparatus may comprise a second piston which is moveable
20 under action of ambient pressure to reduce the volume of the third fluid receiving
chamber. The chambers and pistons may be arranged with the second piston exposed
to ambient pressure and being disposed at one end of the third chamber, the first
piston disposed between the third chamber and the first chamber, and the second
chamber beyond the first chamber.

25

Where the power generation apparatus comprises a portion of tubing this may partly define the third chamber, with the second piston defining one end of the third chamber and the first piston defining the other end of the third chamber.

- 5 The second piston may be lockable against movement relative to a main body of the power generation apparatus. The second piston may be arranged for sliding axial movement relative to the tubing and may be lockable against such movement.

The power generation apparatus may comprise control means for controlling flow of
10 fluid from the first chamber to the second chamber via the fluid communication path. The control means may comprise a valve.

The control means may be arranged to open the valve to allow flow of fluid via the fluid communication path to generate electricity when in receipt of a signal indicating
15 that power is required and to hold the valve closed at other times.

Such a signal might be generated at predetermined times and/or under predetermined conditions.

20 According to another aspect of the present invention there is provided a downhole communication system comprising:

communication apparatus comprising at least one of a transmitter and a receiver; and

downhole electrical power generation apparatus as defined above for
25 supplying electrical power to the communication apparatus.

The communication apparatus may comprise a control unit which may be arranged to send a signal, indicating that power is required, to the downhole electrical power generation apparatus at predetermined times and/or under predetermined conditions.

5

The predetermined conditions may comprise the fact that signals are to be transmitted by the communications apparatus.

According to another aspect of the present invention there is provided a well
10 installation comprising downhole metallic structure and, disposed within the metallic structure, downhole electrical power generation apparatus as defined above.

According to another aspect of the present invention there is provided a well
15 installation comprising a downhole metallic structure and a downhole communication system as defined above.

The downhole metallic structure may be used as a signal channel by the downhole communication system.

20 According to a further aspect of the present invention there is provided a method of downhole electrical power generation comprising the steps of using ambient downhole pressure to cause flow of fluid from a first fluid receiving chamber via a fluid communication path to a second fluid receiving chamber and using the flow of fluid from the first chamber to the second chamber to operate a turbine generator to
25 generate electrical power.

The method may comprise the step of pressurizing a third fluid receiving chamber using ambient pressure and in turn using the pressure in the third fluid receiving chamber to cause the flow of fluid from the first fluid receiving chamber to the second
5 fluid receiving chamber.

Clearly the optional features described with reference to any one of the above aspects of the invention may also be used with any of the other aspects of the invention, where context allows. Thus for example the optional apparatus features are equally
10 pertinent to the above defined method, and could be restated here with the necessary changes in language but are omitted for the sake of brevity.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

15

Figure 1 schematically shows a well installation including a downhole communication system which in turn includes a downhole electrical power generation apparatus;

Figure 2 shows more detail of some of the downhole components of the well
20 installation shown in Figure 1; and

Figure 3 schematically shows part of an alternative downhole tool which is similar to a downhole tool shown in Figure 2.

Figures 1 and 2 schematically show a well installation comprising downhole metallic structure 1 in the form of a tubular metallic casing 11 and including a downhole communication system. A downhole tool 2 is disposed within the casing 11 and arranged for communicating with a surface unit 3.

5

In this embodiment the downhole tool 2 comprises a length of drill stem/production tubing 21 which is sealed at both ends and is supported within the casing 11 by a packer 22 at an upper end and a conductive centraliser 23 at a lower end. As alluded to above, such tubing 21 is typically used in the oil and gas industry as part of a drill stem when drilling a well or part of production tubing when extracting product from a well. Similarly, packers 22 and conductive centralisers 23 are used in such circumstances. Here, however, these components are used as part of the downhole tool 2. The packer 22 and conductive centraliser 23 ensure that there is good electrical contact between the tubing 21 and the casing 11 at spaced locations, i.e. at each end of the length of tubing 21.

The downhole tool 2 is shown in more detail in Figure 2. The downhole tool 2 comprises a communications and control unit 4 which comprises a transceiver module 41, a control module 42 and a sensor module 43. The control module 42 controls operation of the transceiver module 41 in sending signals concerning local parameters detected by the sensor module 43 such as pressure. The transceiver module 41 is electrically connected to the piece of tubing 21 for the application of signals onto the tubing 21 and the extraction of signals from the tubing 21.

The surface unit 3 similarly comprises a transceiver module 31 which has one terminal connected to the downhole metallic structure, i.e. to the casing 11 and another terminal connected to ground. The transceiver modules 41, 31 are arranged to communicate with one another by sending low frequency and high current electrical signals via the metallic structure, in particular the casing 11, of the well installation.

When in transmit mode, the downhole transceiver module 41 has a high power consumption which is necessary to apply large enough signals to the tubing portion 21 and hence casing 11 so that they may reach the surface transceiver 31.

10

In previous systems used by the Applicants, such power has been provided for, in general terms, by a large array of batteries. In the present embodiment, whilst some power may be provided to the downhole communication and control unit 4 by batteries, the majority of power required for signalling is provided by another source.

15

Within the tubing portion 21, two fluid receiving chambers 21a and 21b are provided. The first and second fluid receiving chambers 21a, 21b are separated by a dividing wall 24. An opening 24a is provided in this dividing wall 24 and this opening 24a acts as a fluid communication path between the first chamber 21a and the second chamber 21b. A valve 25 is provided in the opening 24a to control the flow of fluid from the first chamber 21a to the second chamber 21b. In particular, if the valve 25 is closed, flow of fluid from the first chamber 21 to the second chamber 21b is, to all intents and purposes, prevented.

20

A turbine generator 26 is provided in the region of the opening 24a such that when fluid flows from the first chamber 21a into the second chamber 21b this causes the turbine generator to operate thus generating electricity. The turbine generator 26 is electrically connected to the communications and control unit 4 and as such electricity
5 generated by the turbine generator 26 may be used by the communications and control unit 4. In particular, this electrical power may be used in transmitting signals from the downhole tool 2 towards the surface.

In the present embodiment, the first fluid receiving chamber 21a is filled with oil or
10 water and the second fluid receiving chamber 21b is filled with air. The second fluid receiving chamber is sealed against the ingress or egress of the fluid other than via the opening 24a. Similarly, the first fluid receiving chamber 21a is sealed against the ingress or egress of fluid other than via the opening 24a. However, whilst the second fluid receiving chamber 21b has a simple blank end such that it has a constant
15 volume, the first fluid receiving chamber 21a is sealed, at its end remote from the dividing wall 24, by a movable piston 27. This moveable piston 27 is movable axially within the tubing portion 21 and has a sealed sliding fit therewith. The piston 27 is generally cylindrical so as to match the internal shape of the tubular portion 21 and is provided with O-ring seals.

20

In the present embodiment, the tool 2 and hence the tubing portion 21 has an overall length of approximately 200 metres. The dividing wall 24 is provided approximately mid-way along this length. Thus, the second fluid receiving portion 21b has an effective length of in the order of 100 metres. Furthermore, when the piston 27 is slid

so as to maximise the volume of the first fluid receiving chamber 21a, this has a length of approximately 90 metres.

The face of the piston 27 which faces externally, that is away from the dividing wall 24, is exposed to the surroundings. In the present embodiment the piston 27 is exposed to the surroundings by virtue of apertures A (one of which is shown in the Figures) in the tubing portion 21, which allow fluid into the tubing portion 21 on the external side of the piston 27. Thus, when the downhole tool 2 is disposed in situ downhole, this external face 27 is exposed to the ambient pressure present in the product in the well. Of course this is typically a high pressure environment (say 5000psi).

Whilst the valve 25 is kept closed, the piston 27 will remain generally static.

However, if the valve 25 is opened allowing the oil or water in the first fluid receiving chamber 21 to flow into the second fluid receiving chamber 21b, then the pressure acting on the piston 27 can cause the piston 27 to move and thus drive this flow of fluid from the first fluid receiving chamber 21a into the second fluid receiving chamber 21b.

Of course, whilst this flow occurs, this will drive the turbine causing the turbine generator 26 to generate electricity which is fed to the communications and control unit 4.

As this process occurs, the air in the second fluid receiving chamber 21b will be compressed. However, this should cause no difficulties as the components used to

make the chambers 21a, 21b, in particular the tubing portion 21 and a valve 25 can be components typically used in the oil and gas industry and well able to operate under extreme pressures. Furthermore, even though the pressure in the air of the second chamber 21b may increase by a factor of ten if the piston is allowed to travel along its whole length (i.e. driving 90 metres worth of oil/water into 100 metres of available space in the second chamber 21b), this will not prevent the system working.

For the present embodiment to function the pressure of the air in the second chamber 21b needs to be below the ambient pressure downhole at least in an initial state.

10

As the tool 2 will generally be assembled at the surface, at that stage, the air in the second fluid receiving chamber 21b can conveniently be at one bar (15psi). This means that if the piston 27 moves to its maximum extent downhole, this will drive the air pressure up to say, 10 bar (150psi). However, this pressure is still small compared with the available downhole pressure for driving the piston 27 – say 5000 psi.

15

Of course, the turbine generator 26, the valve 25, and the size of the opening 24a may be chosen with the aim of generating a suitable amount of electricity at a suitable rate.

In alternatives some form of charge storage means, be these for example, rechargeable cells, or capacitors may be provided in the tool 2 to store excess electricity generated during the generation process or to build up power over time for a transmission.

20

The control module 42 is arranged to control the operation of the valve 25 so that insofar as possible, power is only generated by the turbine 26 where it is required by

25

the communications and control unit 4. Thus, the control module 42 can be arranged to open the valve 25 to cause the generation of electricity when signals are to be transmitted. In alternatives the control module 42 can be arranged to open the valve 25 to cause the generation of electricity under predetermined conditions, for example at set times.

At positions between the packer 22 and the conductive centraliser 23 the tubing portion 21 is insulated from the casing 11 to maximise the injection of signals into the casing 11 and extraction of signals from the casing 11. Such insulation may be provided by the provision of an insulating layer on the tubing 21 or the use of insulated centralisers 23a. The length of tubing 21 may have two metallic portions which are insulated from one another by an insulation joint to again help in the injection and extraction of signals. The transceiver 41 can then be connected across the insulation joint.

Of course, the size of the tool described, i.e. using an overall length of approximately 200 metres, is a matter of design choice. If there are lower power requirements or power is required over a shorter time, a smaller unit might be produced. Conversely, if there are larger power requirements or power is required over a longer time, then a longer unit might be provided.

With the embodiment in the present form it is most suited for use in an abandoned well as the tool 2 itself is large and occupies the whole diameter of what would otherwise be drill stem or production tubing.

25

In alternative implementations, it would be possible to have different sized or shaped units which would perhaps be more suitable for use in non-abandoned wells. Such a unit might be locatable in the annulus between two sets of tubing in a well. Such a unit might be arranged as a mandrel tool.

5

Whilst in the present embodiment one of the fluid receiving chambers 21a is filled with a liquid and the other fluid receiving chamber 21b is filled with gas and this the preferred arrangement, this should not be considered as essential.

10 Furthermore, whilst in the present embodiment a piston 27 is provided to control the volume of the first chamber 21a, again this should not be considered essential. In one particular, but less preferred, alternative it might be possible to dispense with the piston 27 altogether and just expose the first chamber 21a directly to the ambient pressure – that is to the product, and allow the product flow through the turbine
15 generator and into the second chamber 21b.

Of course whilst the present embodiment is described in terms of a signalling system, similar power generation apparatus may be used to generate electrical power for different uses.

20

Figure 3 shows an alternative downhole tool 2' which is similar to that described above in relation to Figure 2. Many of the parts and aspects of the operation of this downhole tool are the same as that described above in relation to Figure 2. The same reference numerals are used to denote the common parts between this downhole tool
25 2' and that described above 2 and detailed description of these common parts is

omitted for the sake of brevity. Furthermore, some of the detail of the downhole tool 2' which is the same as that shown above in Figure 2 is also omitted from Figure 3 for the sake of simplicity. Thus, the drawing of the alternative downhole tool 2' shown in Figure 3 and the following description concentrate on the differences between these two tools 2, 2' rather than the similarities. Where some aspect of the tool 2' is not shown in Figure 3 or described in reference to Figure 3, it should be assumed that the corresponding features are the same as in the tool 2 of Figure 2.

Here again, there are first and second chambers 21a, 21b defined within a tubing portion 21 and again a turbine generator 26 is provided between these two fluid receiving chambers 21a, 21b such that flow of fluid, i.e. oil or water, from the first fluid receiving chamber 21a into the second fluid receiving chamber 21b will cause the generation of electricity. The control and operation of this part of the tool is the same as that tool shown in Figure 2 and described above. Here, however, rather than the external face of the piston 27 being directly exposed to the ambient pressure as is in the case of the tool shown in Figure 2, a third fluid receiving chamber 21c is provided.

This third fluid receiving chamber 21c has one end defined by the piston 27 which also defines the end of the first chamber 21a and another end defined by a second piston 28. Again this second piston is arranged to slide axially within the tubing portion 21 and to seal therewith. Thus the third fluid receiving portion 21c is sealed against the ingress or egress of fluid.

In the present downhole tool 2', the third receiving chamber 21c is filled with a gas, for example air, at the point of installation. On installation, the second piston 28 is located in the position shown in dotted lines in Figure 3 and marked 21'. At this point in time, of course, the third fluid receiving chamber 21c is larger and encompasses
5 that region of the tubing marked 21c'.

When the tool 2' is assembled and is at the surface, the second piston 28' is in this position. However, when the tool 2 is first installed downhole, the ambient pressure is allowed to act on the second piston 28 by virtue of the fluid in the well, i.e. product,
10 flowing in through apertures A (only one of which is shown in Figure 3) into the tubing so as to act on the external surface of the second piston 28. This causes the second piston to move from the position shown in the dotted lines 28' to the position shown in solid lines 28. In doing so, the volume of the third fluid receiving chamber 21c is reduced and the gas carried within that volume is compressed. At this point the
15 second piston 28 is locked in position relative to the tubing 21 via a locking arrangement 28a. Thus there is now a high pressure gas in the third receiving chamber 21c due to the pressurisation caused by the application of the ambient pressure.

20 This high pressure gas 21c may be used to drive the first piston 27 when this is desired in the same way as described above with reference to Figures 1 and 2. In particular, when it is desired to generate electricity, the valve 25 may be opened causing the turbine generator 26 to be operated by the flow of fluid from the first chamber 21a to the second chamber 21b. In this instance it is the pressurised gas in
25 the third chamber 21c which is being used (indirectly) to power the generator 26. Of

course the origin of the pressurised gas in the third fluid receiving chamber 21c is still ultimately the ambient pressure, as it was this which was used to charge the third fluid receiving chamber 21c when the tool 2 was installed.

5 The advantage of using this alternative tool 2' is that the effect of, as one might say, taking pressure from the fluid in the well, i.e. product, occurs once and only once when the tool is first initiated. This avoids the situation where there can be a large number of separate operations of the tool over time each of which could change the pressure of the product in the region of the tool 2' at least transiently. This, in turn, is
10 important because one of the things which the tool 2' is most likely to be used for is taking pressure measurements of the product in the well. Thus, in at least some circumstances it might be the case that continued extraction of energy from the fluid by allowing the fluid to operate on the piston 27 of the device shown in Figure 2, could affect the measurement results. This would be particularly the case were
15 pressure measurements to be taken at around the time that energy was extracted from the product. That is to say, if the device of Figure 2 were used to extract energy from the well and then use this to immediately make a pressure measurement, the very act of allowing the piston 27 to move to extract energy from the pressure could cause a change in the localised pressure in the well which in turn could skew the pressure
20 measurement results.

In the alternative tool as shown in Figure 3, this potential problem is eliminated by once and only once using pressure from the local fluid to drive the second piston 28 to its locked position as shown in solid lines in Figure 3.

CLAIMS

1. Downhole electrical power generation apparatus comprising first and second fluid receiving chambers, a fluid communication path for allowing flow of fluid from the first chamber via the fluid communication path to the second chamber and a turbine generator disposed so that fluid flowing from the first chamber via the fluid communication path to the second chamber operates the turbine generator to generate electrical power.
2. Downhole electrical power generation apparatus according to claim 1 in which the second chamber is sealed against the ingress of fluid except for fluid received from the first chamber.
3. Downhole electrical power generation apparatus according to claim 2 in which the second chamber is sealed against the ingress of fluid except via the fluid communication path from the first chamber.
4. Downhole electrical power generation apparatus according to any one of claims 1 to 3 in which the first chamber is sealed against the egress of fluid except for fluid supplied towards the second chamber.
5. Downhole electrical power generation apparatus according to claim 4 in which the first chamber is sealed against the egress of fluid except via the fluid communication path to the second chamber.

6. Downhole electrical power generation apparatus according to any preceding claim which comprises a piston which is moveable to reduce the volume of the first chamber for driving fluid from the first chamber into the second chamber.
- 5 7. Downhole electrical power generation apparatus according to claim 6 in which the piston is moveable under action of ambient pressure.
8. Downhole electrical power generation apparatus according to any preceding claim which comprises pressure transfer means for transferring ambient pressure in
10 the region in which the apparatus is disposed to fluid held in the first fluid receiving portion.
9. Downhole electrical power generation apparatus according to any preceding claim which comprises a third fluid receiving chamber, which is arranged to be
15 pressurised using ambient pressure.
10. Downhole electrical power generation apparatus according to claim 9 when dependent on claim 6 or claim 7 which comprises a second piston which is moveable under action of ambient pressure to reduce the volume of the third fluid receiving
20 chamber.
11. Downhole electrical power generation apparatus according to claim 10 in which the chambers and pistons are arranged with the second piston exposed to ambient pressure and being disposed at one end of the third chamber, the first piston

disposed between the third chamber and the first chamber, and the second chamber beyond the first chamber.

12. Downhole electrical power generation apparatus according to claim 10 or
5 claim 11 in which the second piston is arranged for sliding axial movement relative to the tubing and is lockable against such movement.

13. Downhole electrical power generation apparatus according to any preceding
claim which comprises control means for controlling flow of fluid from the first
10 chamber to the second chamber via the fluid communication path.

14. Downhole electrical power generation apparatus according to claim 13 in
which the control means is arranged to allow flow of fluid via the fluid
communication path to generate electricity when in receipt of a signal indicating that
15 power is required.

15. A downhole communication system comprising:
communication apparatus comprising at least one of a transmitter and a
receiver; and
20 downhole electrical power generation apparatus according to any preceding
claim for supplying electrical power to the communication apparatus.

16. Downhole electrical power generation apparatus according to claim 15 in
which the communication apparatus comprises a control unit which is arranged to

send a signal, indicating that power is required, to the downhole electrical power generation apparatus at predetermined times and/or under predetermined conditions.

17. A well installation comprising downhole metallic structure and, disposed
5 within the metallic structure, downhole electrical power generation apparatus according to any one of claims 1 to 14.

18. A method of downhole electrical power generation comprising the steps of
using ambient downhole pressure to cause flow of fluid from a first fluid receiving
10 chamber via a fluid communication path to a second fluid receiving chamber and using the flow of fluid from the first chamber to the second chamber to operate a turbine generator to generate electrical power.

19. A method according to claim 18 comprising the step of pressurizing a third
15 fluid receiving chamber using ambient pressure and in turn using the pressure in the third fluid receiving chamber to cause the flow of fluid from the first fluid receiving chamber to the second fluid receiving chamber.

Application No: GB0811663.4
Claims searched: 1-19

Examiner: Dr Lyndon Ellis
Date of search: 20 July 2008

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-6, 15, 17, 18	US2003/0116969 A1 (Skinner) Whole document, noting paragraphs 0034, 0035
A	-	US2005/0200210 A1 (Kotsonis)
A	-	US2006/0175838 A1 (Tips)

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

E21B

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
E21B	0041/00	01/01/2006