(12) UK Patent Application (19) GB (11) 2569564 (13) A

(43) Date of A Publication 26.06.2019

(21) Application No: 1721362.0

(22) Date of Filing: 20.12.2017

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(51) INT CL:
E21B 47/005 (2012.01) ***E21B 33/13*** (2006.01)
E21B 29/00 (2006.01) *E21B 37/06* (2006.01)
E21B 37/08 (2006.01)

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(58) Field of Search:
INT CL **E21B**
Other: **EPODOC, WPI, Patent Fulltext**

(54) Title of the Invention: **Improvements in or relating to well abandonment and slot recovery**
Abstract Title: **Abandoning a well and preparing for cement bond log**

(57) Method of abandoning a well leaving production tubing 7 and control lines 15 in place. Tubing 7 is perforated 20a, 20b at a zone of interest which can be at any position in the wellbore spaced from a seal or packer. The tubing 7, casing 33 and annulus can be washed to remove debris and residual fluids after perforation. A self-supporting settable composition 21 is injected through the perforations 20a, 20b into the annulus and allowed to set to support the tubing 7 and secure control lines 15 so that they can be cut and milled away to expose the casing 33. A cement bond log (CBL) is performed on the exposed casing and if the quality of the cement bond is acceptable a cement plug is deployed. The zone of interest can be washed with an acid wash to dissolve the settable composition, cleaning the zone to improve access for the cement bond log. If the quality of cement bond is not adequate, the process can be repeated at a shallower depth.

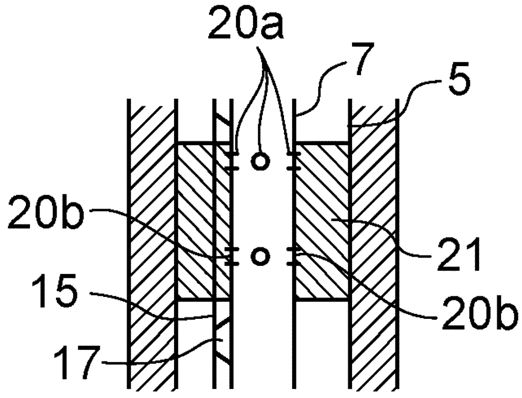

Fig. 2c

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

19 12 18

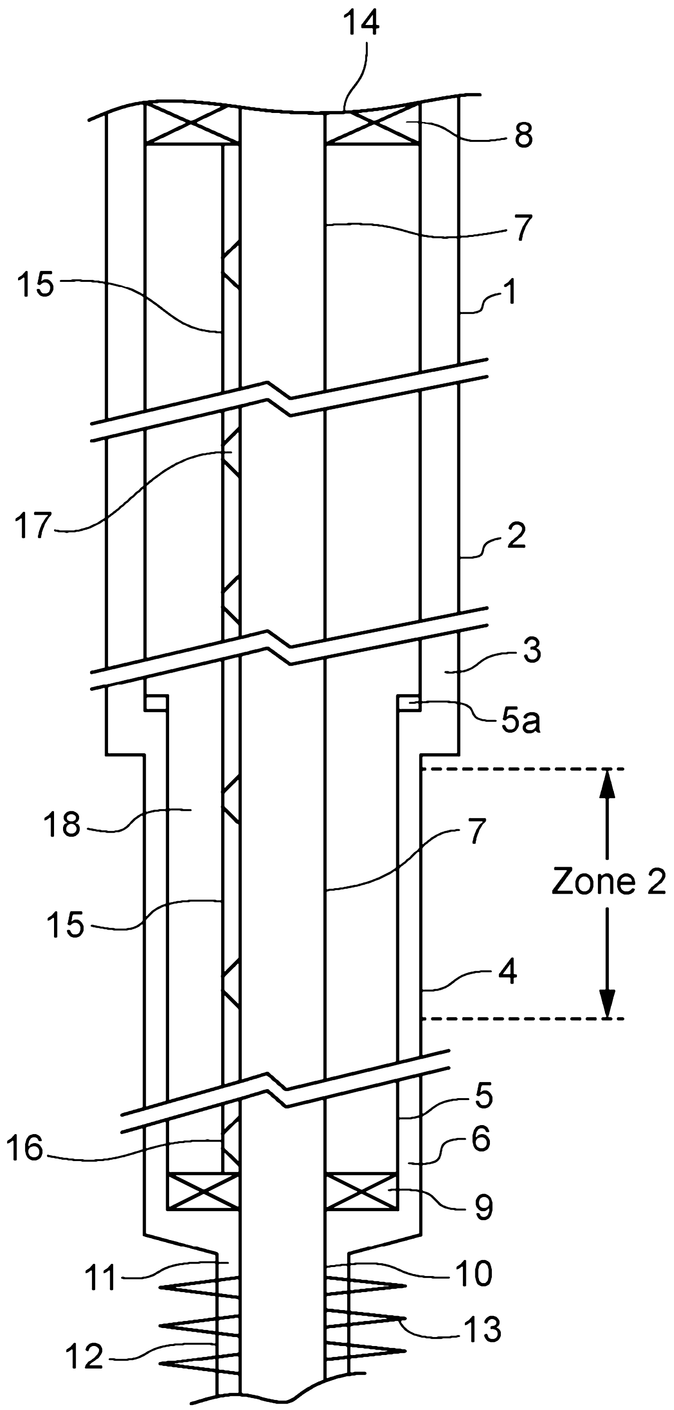

Fig. 1

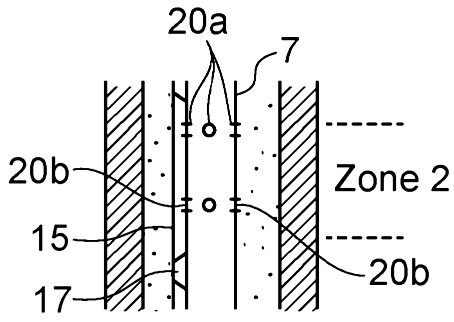

Fig. 2a

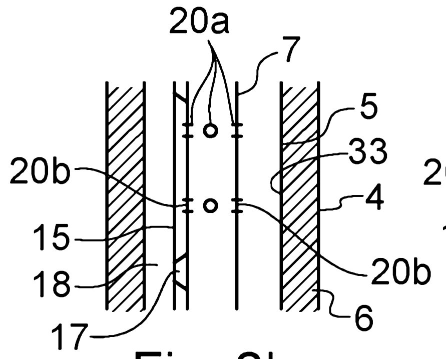

Fig. 2b

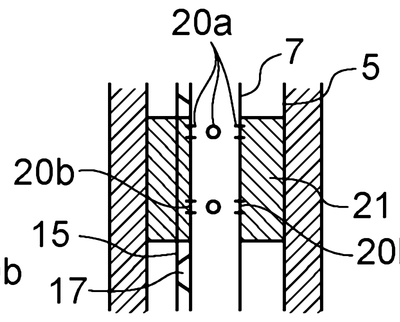

Fig. 2c

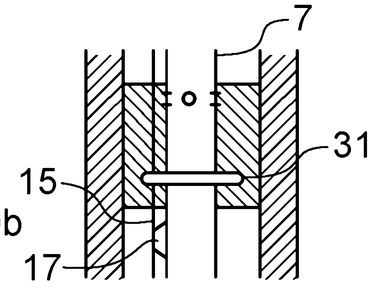

Fig. 2d

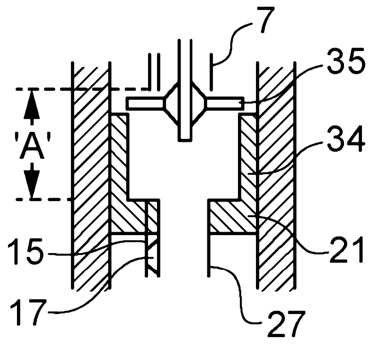

Fig. 2e

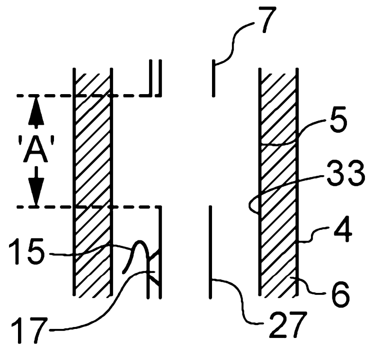

Fig. 2f

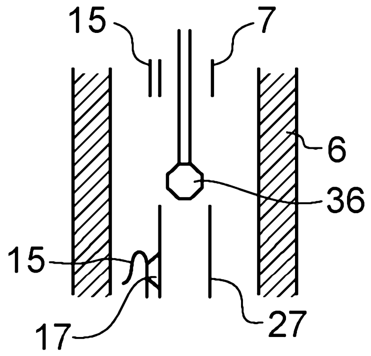

Fig. 2g

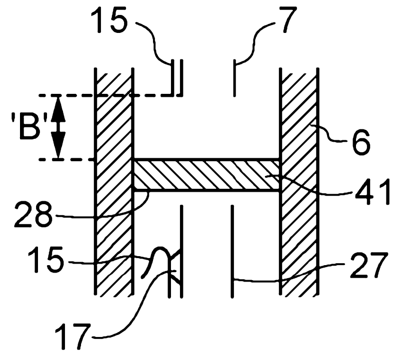

Fig. 2h

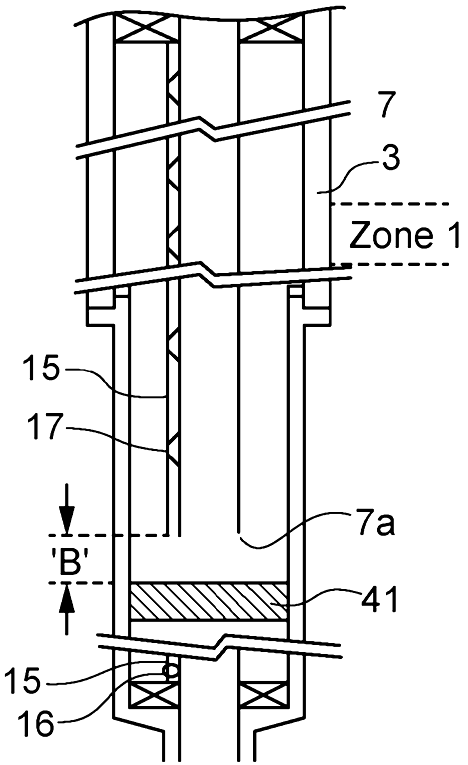

Fig. 3

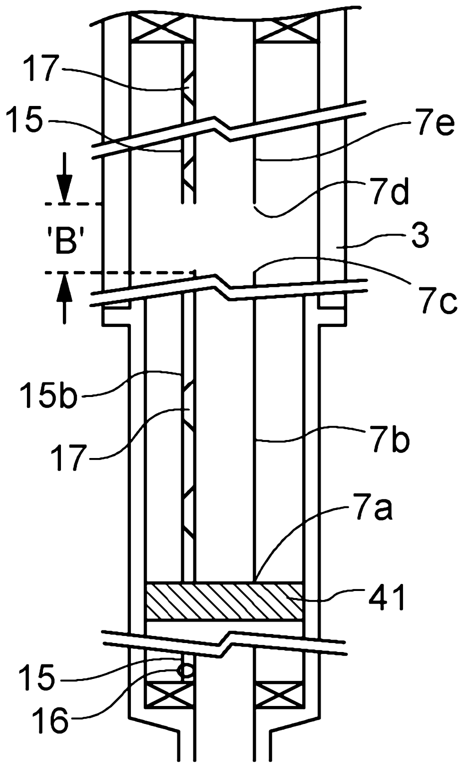

Fig. 4

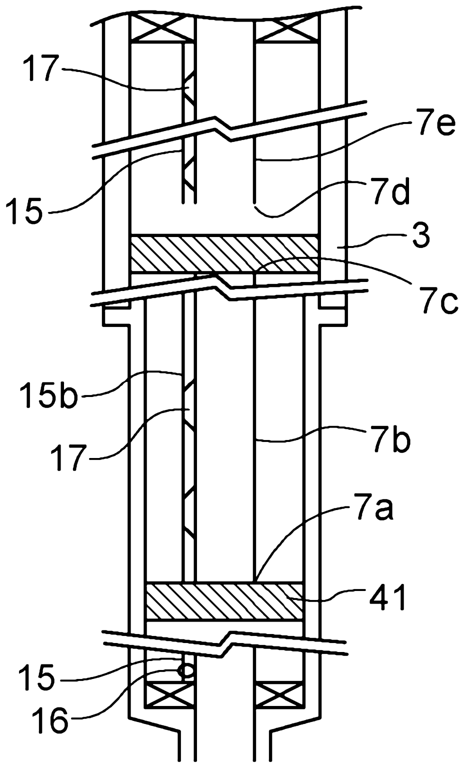

Fig. 5

19 12 18

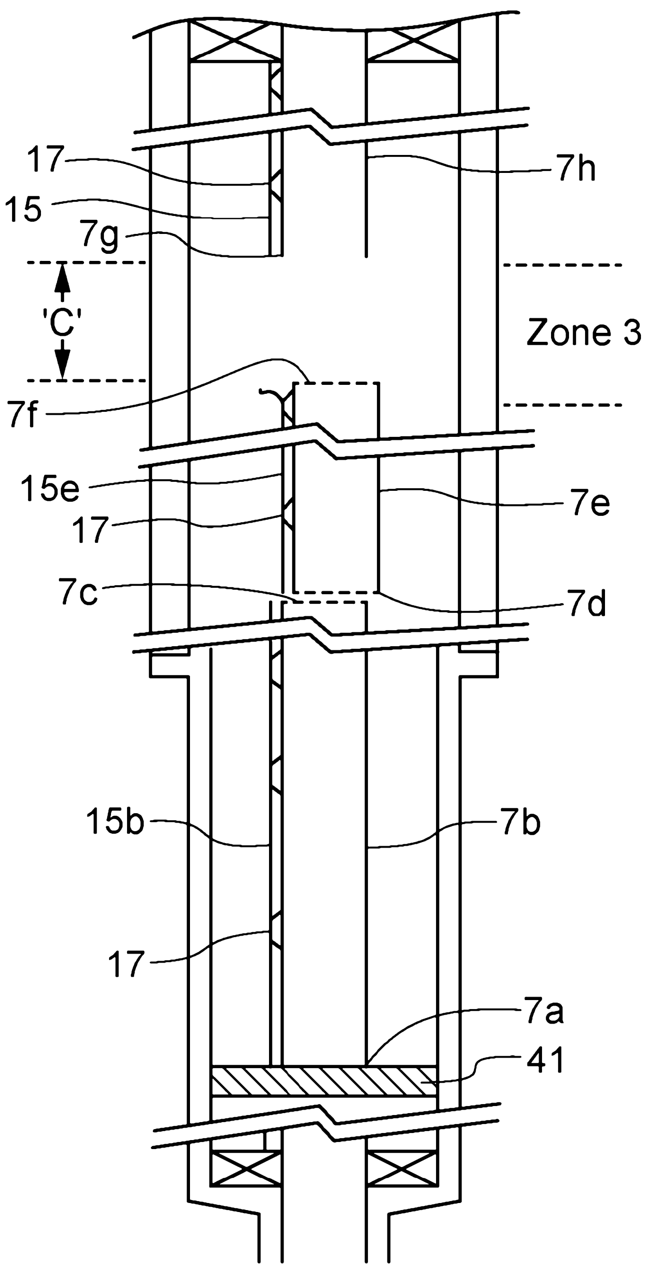

Fig. 6a

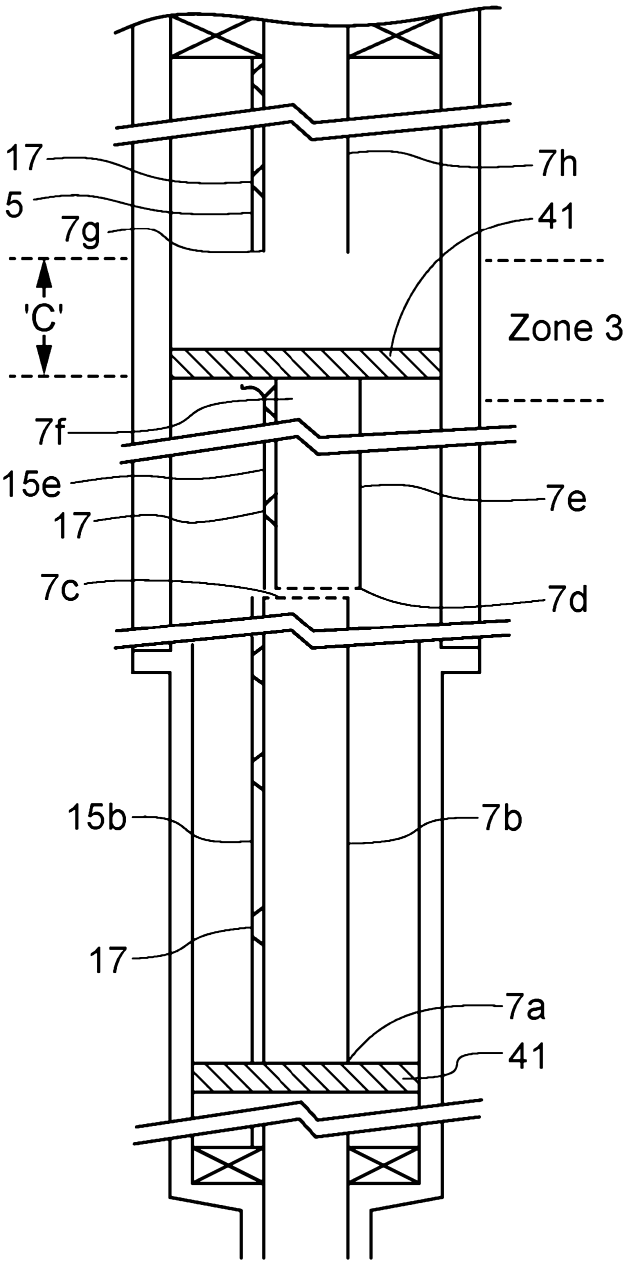

Fig. 6b

19 12 18

IMPROVEMENTS IN OR RELATING TO WELL ABANDONMENT AND SLOT RECOVERY

The invention relates to the field of hydrocarbon exploration and more specifically to methods of efficiently abandoning wells when they have come to the end of their useful life.

In order to make the wellbore safe and to meet regulatory standards, it is necessary to set several plugs within the wellbore to resist any build-up of pressure that may occur in the future. In order to prepare the wellbore for the setting of such plugs it is typically necessary to remove the production tubing from the well. Tubing removal is a costly operation requiring the employment of expensive equipment, such as a drilling rig.

In the course of constructing an oil or gas well, a hole is drilled to a pre-determined depth. The drilling string is then removed and a metal tubular or casing is run into the well. When the casing reaches the bottom of the well, cement is pumped down the casing and displaced up the annulus between the casing and the original wellbore.

The function of the cement is to secure the casing in position and ensure that the annulus is sealed. This process of drilling, running casing and cementing is repeated with successively smaller drilled holes and casing sizes until the well reaches its target depth.

At this point, a final tubular or tubing is run into the well. The tubing is secured at its top and at its bottom end, but it is not cemented in place so as to facilitate potential remedial operations, such as removal and replacement of the tubing in the event that it becomes damaged or corroded. A valve, known as a downhole safety valve, is positioned in the upper part of the tubing typically 500 ft below the wellhead. Should a safety problem occur, this valve can be closed to seal in pressure. Activation of the valve is accomplished by applying pressure from surface down control lines running alongside and clamped to, the tubing.

During the well construction phase, after each cementing operation, confirmation of the quality of the cement sheath around the casing is desired. A typical way of providing such confirmation would be to carry out a cement bond log (CBL).

The CBL will confirm whether the quality of the cement sheath is adequate. If it proves that the CBL shows that the cement quality is not adequate certain remedial operations may be possible. These processes are necessary so that when the construction phase is complete, the well operator has a record demonstrating that the successive annuli are secure. The well may now be put on production, with the hydrocarbons flowing up the tubing and gathered at surface. Over time, which may be several decades, the production of hydrocarbons reduces until the production rate is no longer economically viable, at which point the well has reached the end of its productive life.

The well now needs to be plugged and abandoned. Although regulations vary between jurisdictions, a universal requirement is that the abandoned well should not leak hydrocarbons at any point in the future. In abandoning the well, the operator has the primary legal responsibility to demonstrate to the regulatory authorities that everything practical has been done to ensure a secure abandonment.

Ordinarily, the CBL record would form part of the evidence that the operator would produce to support the case for a securely abandoned well, however in many cases the CBL record may not be available, or the quality of the CBL record may not be adequate, due to the limitations of the technology of the day or due to the acceptance criteria having become more stringent. It may even be the case that the operator has a good CBL, but decides that the risk of a leak is still too high given the uncertainty of the future regulatory framework and associated penalties.

Unless the operator is both able and willing to convince the regulatory authorities that the cement bond is acceptable, they have to contemplate how to arrive at a position of acceptance. In many cases, it is decided that the best method is to gain access to the cemented casing by removing the final tubing from the well. In order to gain access to the casing for which a new CBL needs to be carried out, the operator needs to remove the final tubing from at least that point up to the surface of the well. This is because cement bond logs cannot be made through two strings of metal tubular.

One method of doing this would be to pull the entire tubing string, alternatively the tubing can be cut just below the point of interest and the tubing above pulled from the well, leaving the lower portion in place. In either event, costly surface equipment such as a drilling rig capable of pulling tubing needs to be provided. A CBL can now be carried out. In the event that the CBL is shown to be good, the operator can set a cement plug inside the casing and move up the well to the next zone of interest. This may be repeated several times until the entire well is deemed secure.

If however the CBL shows the cement to be of insufficient quality, the operator now has the choice either to mill away the casing and the old cement over a sufficiently long section and place a new cement plug or alternatively to perform a remedial cement job. Remedial cementing would involve perforating the casing, washing out as much of the old cement as possible and squeezing new cement through the perforations, known as a perforate, wash and squeeze job, whilst also leaving a cement plug within the casing. It can now be seen that the default option for the situation where existing data shows the cement to be of uncertain quality, or where there is no data available is to remove the tubing from at least that point up to the surface of the well. As has been explained, this is necessarily an expensive process.

However, it can be seen that removal of the tubing is merely a facilitator in determining whether the cement bond is adequate, if the cement bond is shown to be inadequate then tubing removal has been justified, but if the cement bond is adequate then tubing removal has proved to be an unwarranted expense. Even in the situation where all the CBL's show that the cement quality is good, the operator still has to remove the upper part of the tubing. This is because an upper cement plug needs to be set just below the wellhead.

WO2016/156862 discloses a method of determining the condition of a cement bond of a casing in a wellbore. The method comprises perforating a tubing in the wellbore at a zone of interest and displacing a settable composition through the perforations into the annulus between the casing and tubing to secure the tubing. The method also comprises cutting the tubing and assessing the status of the cement bond of the casing.

In this disclosure the settable compound is described as a resin, gel or cement, with cement typically being used. In order to contain the resin, gel or cement in the annulus over the zone of interest, the zone of interest must be bounded by a packer on its lower side. This is because the resin gel or cement, being sufficiently fluid-like to displace through the perforations, will simply fall by gravity through the annulus to the first surface it reaches. For a near vertical well this will be a packer and for a horizontal well it will collect on the low side over an extended length of the annulus. Thus once set the settable compound will not entirely fill the annulus to make a secure connection between the production tubing and the casing, unless the settable compound is supported by a packer or like seal across the annulus.

It is an object of at least one aspect of the present invention to obviate or at least mitigate the foregoing disadvantages of prior art methods for abandoning a well.

According to a first aspect of the present invention there is provided a method for abandoning a well, the well including a cemented section behind casing in a wellbore and production tubing within the casing at the cemented section, comprising the steps in order:

(a) perforating the production tubing in the wellbore at a zone of interest at the cemented section at a location;
(b) passing a self-supporting settable composition through the perforations into the annulus between the casing and the production tubing over the zone of interest;
(c) allowing the self-supporting settable composition to set to secure the production tubing to the casing over the zone of interest;
(d) cutting the production tubing at the zone of interest to access the casing at the cemented section; and
(e) performing a cement bond log to assess the quality of the cement bond at the cemented section over the zone of interest.

In this way, the self-supporting settable composition will remain in the zone of interest and therefore the zone of interest may be at any position along the production tubing.

The zone of interest may have an upper edge and a lower edge, the lower edge being spaced a distance above a seal within the annulus. The zone of interest may comprise a length in the range 30m to 90m. The length may be in the range 30m to 60m.

The self-supporting settable composition may be a self-supporting resin. The self-supporting settable composition may be a self-supporting gel. In an embodiment, the self-supporting settable composition is based on Thermatek™ rigid setting fluid available from Halliburton Corporation, USA. More preferably, the self-supporting settable composition is an acid washable composition. In this way the composition can be removed after use. The method may comprise deploying an injection tool to displace a pre-determined amount of self-supporting settable composition through the perforations into the annulus.

The method may include displacing the self-supporting settable composition into the annulus as a foam. In this way, fluids which are typically not self-supporting may be arranged to be so.

The method may comprise running a perforating tool through the tubing to a predetermined and/or desired depth.

The method may comprise perforating the tubing using explosive charges or a punch tool.

The self-supporting settable composition supports the tubing and secures the tubing in position. The method may comprise securing the tubing rigidly in position in the wellbore. Preferably, the method comprises securing the tubing rigidly by allowing the self-supporting settable composition to set hard in the annulus between the casing and tubing. The method may comprise securing the tubing temporarily in position before the cutting and/or milling operation is started.

The method may comprise securing one or more control lines in the annulus over the zone of interest. In this way, the control lines can be left in the well between the production tubing and the casing.

The method may comprise providing a tubing cutter to cut a slot through a wall of the production tubing. The method may comprise deploying a milling tool to mill away the tubing. The method may comprise milling away the securing self-supporting settable composition in the annulus between the casing and the tubing. The method may comprise milling away the one or more control lines in the annulus between the casing and the tubing. The method may comprise milling in an upward or downward direction. The method may comprise milling away the tubing up to the top of the self-supporting securing settable composition.

The method may comprise cleaning an inside of the production tubing and the annulus over the zone of interest between perforating the tubing and displacing the self-supporting settable composition. This washing step removes debris created during the perforating step and provides clean surfaces on the outside of the production tubing and inside of the casing for the self-supporting settable composition to adhere to more effectively.

The method may comprise washing away the set self-supporting settable composition after the production tubing has been cut.

Preferably this wash is an acid wash. In this way the set self-supporting settable composition is dissolved. This method may comprise soaking the self-supporting settable composition in the acid wash to aid removal. By removing the self-supporting settable composition, the inner surface of the casing is free from any debris or deposits for logging to be undertaken.

The method may comprise pulling the tubing out of the casing if the cement bond is shown to be of poor quality. The method may comprise deploying a cement plug if the cement bond is shown to be of adequate and/or good quality.

The method may further comprise assessing the quality of the cement of a second zone by running a tubing cutter tool in the tubing and cutting the tubing at the upper end of the second zone. The method may comprise cutting the tubing and dropping the cut tubing further downhole. By dropping the tubing further downhole the second zone is exposed and the quality of the cement of a second zone may be assessed.

The method may further comprise repeating the steps at a shallower depth in the well. This will be required where one or more control lines are present in the annulus.

The method may comprise assessing the quality of the cement bond at multiple zones. The method may comprise running a tubing cutter tool in the tubing and cutting and/or milling the tubing at a second and/or further zone to expose the cement bond to allow assessment of the quality of the cement bond.

The method may comprise positioning the cutting tool higher up the well in the event a cement bond is not identified in the second and/or further zone. The method may comprise making further cuts to the tubing and exposing cement bonds until a zone with good quality cement is identified.

It will be appreciated that wells vary in complexity and there may be either more or less zones of interest than described above, however it will also be appreciated that the sequences of operation described heretofore can be applied as many times as are necessary and are not limited to two zones of interest.

In the description that follows, the drawings are not necessarily to scale. Certain features of the invention may be shown exaggerated in scale or in somewhat schematic form, and some details of conventional elements may not be shown in the interest of clarity and conciseness. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce the desired results.

Accordingly, the drawings and descriptions are to be regarded as illustrative in nature, and not as restrictive. Furthermore, the terminology and phraseology used herein is solely used for descriptive purposes and should not be construed as limiting in scope. Use of terms such as “upper” and “lower” are considered relative and though the well bore is drawn in the ideal vertical orientation, it will be appreciated that this may be deviated. Language such as "including," "comprising," "having," "containing," or "involving," and variations thereof, is intended to be broad and encompass the subject matter listed thereafter, equivalents, and additional subject matter not recited, and is not intended to exclude other additives, components, integers or steps.

Likewise, the term "comprising" is considered synonymous with the terms "including" or "containing" for applicable legal purposes.

All numerical values in this disclosure are understood as being modified by "about". All singular forms of elements, or any other components described herein including (without limitations) components of the apparatus are understood to include plural forms thereof.

There will now be described, by way of example only, various embodiments of the invention with reference to the drawings, of which:

Figure 1 shows a sectional diagram of a typical well with two strings of casing, production tubing installed.

Figures 2a to 2h show sectional diagrams of a well demonstrating the typical sequence of operations to assess the condition of a cement bond at zone 2 according to an embodiment of the present invention;

Figures 3 to 5 show sectional diagrams of a well demonstrating the typical sequence of operations to assess the condition of a cement bond at a zone according to a further embodiment of the invention; and

Figure 6a and 6b shows sectional diagrams of a well demonstrating the typical sequence of operations to assess the condition of a cement bond at further zone according to a yet further embodiment of the invention.

Reference is initially made to Figure 1 of the drawings which illustrates a portion of a typical well with two strings of casing and tubing installed. The upper section of wellbore 1 was drilled to a certain depth, after which casing 2 was run into the well. Cement 3 was set over a portion of the outside of the casing 2, sealing the annulus between the casing 2 and the wellbore 1. The next section of wellbore 4 was then drilled to the target depth of the well. A next section of casing 5 was run into the well, suspended inside the first casing 2 with a hanger 5a and likewise cemented 6 to seal the annulus between the second casing 5 and the wellbore 4. Production tubing 7 was then run into the wellbore and suspended at its upper end with a hanger 8 and anchored at its lower end by liner hanger system providing a packer 9. Below the packer 9, a production liner 10, was cemented 11 to a further section of wellbore 12. The liner 10 is open towards the hydrocarbon reservoir via perforations 13. The design and configuration of the production liner 10 may vary significantly from what is illustrated herein, however this will be appreciated by a person skilled in the art and not further described herein. The upper end 14 of the wellbore 1 is not shown, but those skilled in the art will appreciate that an upper completion would be present as would other components such as a sub-surface safety valve. For clarity, only parts required to describe the invention are illustrated.

In the production tubing 7 there may be located permanent downhole gauges 16 such would be required for measuring pressure and temperature. These gauges 16 are connected to and controlled from the surface via a control line 15. The control line 15 may be a single cable or a bundle of cables which are attached via couplings 17 to the production tubing 7 at intervals along its length. While the control line 15 is described as a gauge control line, it will be appreciated that the control line 15 may be any line running in an annulus 18 behind a tubular 7 in the wellbore 1,4,12. Such a line may be a tool control line, a communication line, a chemical injection line or the like. The line may be used to transmit electric or fibre-optic signals, electric power, hydraulic fluid, scale inhibiting chemicals and similar.

When the time comes to abandon the well, in the prior art, the production tubing 7 and control lines 15 would need to be removed using a rig.

Now referring to Figures 2a-h of the drawings there is shown a typical sequence of operations according to an embodiment of the present invention and in particular show zone 2 in detail. The well is as shown in Figure 1, like parts have been given the same reference numeral to aid clarity. According to the present invention, the first operation is to perforate the tubing. In Fig. 2a, a perforating tool (not shown) is run through the tubing 7 to a first desired depth and explosive charges produce holes 20a in the tubing 7. The perforating tool (not shown) is moved to a second desired depth and explosive charges produce holes 20b in the tubing 7. Alternatively, the perforating tool can be moved along the tubing 17 to create holes 20 across the entire zone 2. The perforating tool 19 may alternatively punch holes 20 in the tubing 7. Note that zone 2 can be at any position along the tubing 7 and does not have to be located at the packer 9 as in the prior art arrangement of WO2016/156862.

The next step is to wash the zone 2. A washing tool (not shown) is inserted through the tubing 7. The tool pumps a wash fluid through the perforations 20a,b while rubber cups both direct fluid through the holes 20a,b and wipe the wall 33 of the production tubing 7. The wash fluid removes dirt, debris and fines which may be in the annulus 18 over the zone 2 (see Fig. 2a). The wash fluid also cleans the wall of the tubing 7 and the casing 5 over the zone 2 which bound the annulus 18. This cleaning will assist in placement of the settable self-supporting composition 21 by ensuring that the annulus 18 is clear and that there are no materials on the walls which would prevent the composition 21 adhering to the walls. The cleaned arrangement is illustrated in Fig. 2b.

In Fig. 2c, a downhole tool (not shown) deploys a pre-determined amount of a self-supporting settable composition 21, through the lower set of perforations 20b into the annulus 18 between the casing 5 and the tubing 7. In this embodiment, a fluid based on Thermatek™, a rigid setting fluid available from Halliburton Corporation, is used. The fluid 21 is injected as a foam through the perforations 20b and directed towards the upper perforations 20a. By creating a foam from a fluid, gas is introduced to reduce the weight of the fluid and make it self-supporting. By self-supporting we mean that the composition 21 will remain in the annulus 18 in the area of the holes 20 and not fall down the annulus 18 via gravity. Preferably the composition 21 is designed to adhere to the walls of the tubing 7 and casing 5. Those skilled in the art will recognise other compositions such as gels and resins can also be used which are settable and self-supporting. When the pre-determined amount of composition 21 has been deployed through the lower set of perforations 20b the level of composition 21 has reached the upper set of perforations 20a in the tubing 7. The downhole tool may have sensors to detect composition 21 coming back into the tubing 7 through the upper set of perforations 20a. Alternatively, the self-supporting settable composition 21 is injected through sets of perforations 20, where perforations are made along the entire length of the zone. The downhole tool may include seals or cups to direct the composition 21 into the annulus through the perforations 20.

The composition 21 is then allowed to set hard, thus securing the tubing 7 and control line 15 rigidly in preparation for the next operations. The composition 21 is selected such that, when set, it provides a suitable compressive strength both to hold the tubing 7 and control lines 15 and be cut through without movement. In Fig 2d, a tubing cutter (not shown) is deployed, cutting a slot 31 through the wall of the tubing 7 and the control line 15, and Fig. 2e shows a tubing mill 35 deployed through, and milling away the tubing 7 and the control line 15 up to the top of the previously placed composition 21. Milling of the production tubing 7 and the control line 15 is possible by virtue of there being fixed rigidly in a solid composition 21. Thus a portion of the production tubing 7 and the control line 15 are removed from the wellbore.

The length of tubing 7 and control line 15 milled away is pre-planned and is labelled 'A' and might typically be 60m. The tubing mill 35 is removed from the well. A layer 34 of set composition 21 may be left adhering on the wall of the casing 5 over the zone 2, see Fig. 2e. The next step is to wash away the composition 21 including the layer 34. This is typically done by running a washing tool (not shown) through the milled section. A fluid capable of dissolving and/or dispersing the composition 21 is pumped into the zone. An acid wash is typically used with the composition 21 being acid soluble and permeable. The acid dissolves the composition 21 and cleans the wall 33 of the casing 5 as illustrated in Fig. 2f. In this way any later applied cement will provide a good seal to the casing 5 which will limit the possibility of leak paths existing up the walls of the casing. Additionally, a better quality cement bond log will be obtained.

In Fig. 2g, a cement bond logging tool 36 is deployed through the tubing 7 to assess the quality of the cement 6 of zone 2. If the cement is shown to be of poor quality, then the well is suspended pending deployment of a rig to pull the tubing 7. However, if the cement 6 is shown to be of adequate quality the next operation, as shown in Fig. 2h, is to run a cementing tool (not shown) and deploy a cement plug 41 at the lower end of the milled section 'A'.

Typically, the cement plug 41 might be 30m to 90m thick. If the cement plug 41 is sufficient for well abandonment then the method is complete. Those skilled in the art will be aware that some form of barrier is required, such as a bridge plug to support the cement until such time as it hardens.

Alternatively, if the cement plug 41 is of insufficient length, then further cement plugs will be required. At the end of the method shown at Fig. 2h there will be a gap ‘B’ of 30m for example, between the lower end of the tubing 7a and the top of the cement plug 41.

Figure 3 shows the state of the well after the operations of figs 2a-h. The lower part of the well (zone 2) has been secured and a gap ‘B’ has been left between the lower end of the tubing 7a and the top of the cement plug 41. The next operation is to assess the quality of the cement over zone 1. However due to the gap ‘B’ left below the lower end of the tubing 7a it is not necessary to repeat the milling operation of Fig. 2e. In order to expose the cement 3 of zone 1 for assessment of the cement quality, the steps shown in Figs 2a-d are carried out at a single cutting point with the tubing 7 and control line 15 being cut at the upper end of zone 1. Upon completing an acid wash after the cut, the lower part of the tubing 7b together with the attached control lines 15b are able to fall under gravity until they land on top of the cement plug 41. If the well does not include control lines 15, then simply running a tubing cutter and cutting the tubing 7 at the upper end of zone 1, will cause the lower part of the tubing 7b to fall and land on the cement plug 41.

Figure 4 shows the lower part of the tubing 7b and control lines 15b with the lower end 7a of tubing 7b located on the cement plug 41. There is now a gap of length ‘B’ between the upper end 7c of the lower part of the tubing 7b and the lower end 7d of the upper part of the tubing 7e. Note that the control lines 15 do not lie across the gap. This gap 'B 'has now exposed zone 1 for assessment of the quality of the cement 3. In a similar manner as previously described, a cement bond logging tool now assesses the cement quality and if poor, the well is suspended until a rig is available to pull the tubing 7e from the well. If the cement quality is good, then, again as previously described, a cementing tool is run to place a cement plug 42 in the lower part of gap 'B'. In the case where there are only two zones of interest, operations concerning the tubing 7b and 7e are complete and the final state of the well is shown in figure 5.

The term "upper part" in this context means that this part is closer to the surface than the "lower part". In general, relative terms such as "upper" and "lower" are used to indicate directions and locations as the apply to the drawings.

If the cement quality at zone 1 is poor, an alternative to pulling the tubing 7e and control lines 15e from the well is to repeat the method as described in Figs. 2a-d with an acid wash if control lines 15 are present at a shallower depth in the well and make a further cut in the tubing as shown in Figure 6a.

Figure 6a shows that when the further cut in the tubing 7 and control line 15 is made the cut section of tubing 7e and associated control line 15e drops down the well onto the previously cut tubing section 7b and exposes a new section of casing for evaluation of the cement bond. The tubing 7e and associated control line 15e with its lower end 7d is located on the upper end 7c of the lower part of the tubing 7b. There is now a gap of length 'C' between the tubing end 7f of the tubing 7e and the lower end 7g of the upper part of the tubing 7h. This gap ‘C” has now exposed zone 3 for assessment of the quality of the cement 3.

As previously described, a cement bond logging tool now assesses the cement quality and if the cement quality is good, a cementing tool is run to place a cement plug 42 in the lower part of gap ’C’ as shown in Figure 6b.

If the cement quality is poor at zone 3, the cut and drop operation is repeated by moving the cutting tool upward in the wellbore to depths closer to the surface and a further cuts in the tubing and control line are made until a zone with good quality cement is identified and a cement plug may be placed. By applying this cut and drop operation it is not required to provide costly surface equipment such as a drilling rig in order to pull the tubing and perform remedial operations.

It will be appreciated that wells vary in complexity and there may be either more or less zones of interest than described above, however it will also be appreciated that the sequences of operation described heretofore can be applied as many times as are necessary and are not limited to two zones of interest.

Throughout the specification, unless the context demands otherwise, the terms 'comprise' or 'include', or variations such as 'comprises' or 'comprising', 'includes' or 'including' will be understood to imply the inclusion of a stated integer or group of integers, but not the exclusion of any other integer or group of integers. Furthermore, relative terms such as “upper”, “lower” and the like are used herein to indicate directions and locations as they apply to the appended drawings and will not be construed as limiting the invention and features thereof to particular arrangements or orientations.

The foregoing description of the invention has been presented for the purposes of illustration and description and is not intended to be exhaustive or to limit the invention to the precise form disclosed. The described embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilise the invention in various embodiments and with various modifications as are suited to the particular use contemplated. Therefore, further modifications or improvements may be incorporated without departing from the scope of the invention as defined by the appended claims.

CLAIMS

1. A method for abandoning a well, the well including a cemented section behind casing in a wellbore and production tubing within the casing at the cemented section, comprising the steps in order:
   (a) perforating the production tubing in the wellbore at a zone of interest at the cemented section at a location;
   (b) passing a self-supporting settable composition through the perforations into the annulus between the casing and the production tubing over the zone of interest;
   (c) allowing the self-supporting settable composition to set to secure the production tubing to the casing over the zone of interest;
   (d) cutting the production tubing at the zone of interest to access the casing at the cemented section; and
   (e) performing a cement bond log to assess the quality of the cement bond at the cemented section over the zone of interest.

2. A method according to claim 1 wherein the zone of interest has an upper edge and a lower edge, the lower edge being spaced a distance above a seal within the annulus.

3. A method according to claim 1 or claim 2 wherein the zone of interest comprises a length in the range 30m to 90m.

4. A method according to any preceding claim wherein the self-supporting settable composition is a self-supporting resin.

5. A method according to any one of claims 1 to 3 wherein the self-supporting settable composition is a self-supporting gel.

6. A method according to any preceding claim wherein the method comprises deploying an injection tool to displace a pre-determined amount of self-supporting settable composition through the perforations into the annulus.

7. A method according to any preceding claim wherein the method includes displacing the self-supporting settable composition into the annulus as a foam.

8. A method according to claim 7 wherein the self-supporting settable composition is a fluid.

9. A method according to any preceding claim wherein the method comprises running a perforating tool through the tubing to a predetermined and/or desired depth.

10. A method according to any preceding claim wherein the method comprises perforating the tubing using explosive charges.

11. A method according to claim 9 or claim 10 wherein the perforating tool is a punch tool.

12. A method according to any preceding claim wherein the method comprises securing the tubing rigidly in position in the wellbore.

13. A method according to claim 12 wherein the method comprises securing the tubing rigidly by allowing the self-supporting settable composition to set hard in the annulus between the casing and tubing.

14. A method according to claim 12 wherein the method comprises securing the tubing temporarily in position before the cutting and/or milling operation is started.

15. A method according to any preceding claim wherein the method comprises securing one or more control lines in the annulus over the zone of interest.

16. A method according to any preceding claim wherein the method comprises providing a tubing cutter to cut a slot through a wall of the production tubing.

17. A method according to any preceding claim wherein the method comprises deploying a milling tool to mill away the tubing.

18. A method according to claim 17 wherein the method comprises milling away the securing self-supporting settable composition in the annulus between the casing and the tubing.

19. A method according to claim 18 wherein the method comprises milling away the one or more control lines in the annulus between the casing and the tubing.

20. A method according to any one of claims 17 to 19 wherein the method comprises milling in an upward direction.

21. A method according to any one of claims 17 to 19 wherein the method comprises milling in a downward direction.

22. A method according to any one of claims 17 to 20 wherein the method comprises milling away the tubing up to the top of the self-supporting securing settable composition.

23. A method according to any preceding claim wherein the method comprises pulling the tubing out of the casing if the cement bond is shown to be of poor quality.

24. A method according to any preceding claim wherein the method comprises deploying a cement plug in the casing if the cement bond is shown to be of sufficient quality.

25. A method according to any preceding claim wherein the method comprises assessing the quality of the cement of a second zone by running a tubing cutter tool in the tubing and cutting the tubing at an upper end of the second zone and dropping the cut tubing further downhole so that the second zone is exposed for assessment.

26. A method according to any preceding claim wherein the method further comprises repeating the steps at one or more shallower depths in the well.

27. A method according to claim 1 wherein the steps are performed on separate trips in the wellbore.

28. A method according to claim 1 wherein the two or more steps are performed on the same trip into the well bore.

Intellectual Property Office

Application No:	GB1721362.0	**Examiner:**	Brendan Churchill
Claims searched:	1-28	**Date of search:**	13 February 2018

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
Y	1, 3-28	WO 2016/156862 A2 [WARDLEY] See, page 5 lines 1-7, page 13 and figures 3a-3e
Y,&	1, 3-28	US 6664215 B1 [TOMLINSON] See column 6, lines 11-21
Y,&	1, 3-28	Halliburton Communications, 2005, "Thermatek Service", www.halliburton.com, Available from: http://www.halliburton.com/public/pe/contents/Data_Sheets/web/H/H03829.pdf, [Accessed 6 February 2018] WayBackMachine record dated 7 August 2009: https://web.archive.org/web/20090807012504/http://www.halliburton.com/public/pe/contents/Data_Sheets/web/H/H03829.pdf
A	-	WO 2016/200269 A1 [HYDRA SYSTEMS] See abstract
A	-	US 2011/0220357 A1 [WEATHERFORD] See abstract
A	-	US 8584756 B1 [HALLIBURTON] See abstract

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E21B

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

Intellectual Property Office

EPODOC, WPI, Patent Fulltext

International Classification:

Subclass	Subgroup	Valid From
E21B	0047/005	01/01/2012
E21B	0033/13	01/01/2006
E21B	0029/00	01/01/2006
E21B	0037/06	01/01/2006
E21B	0037/08	01/01/2006