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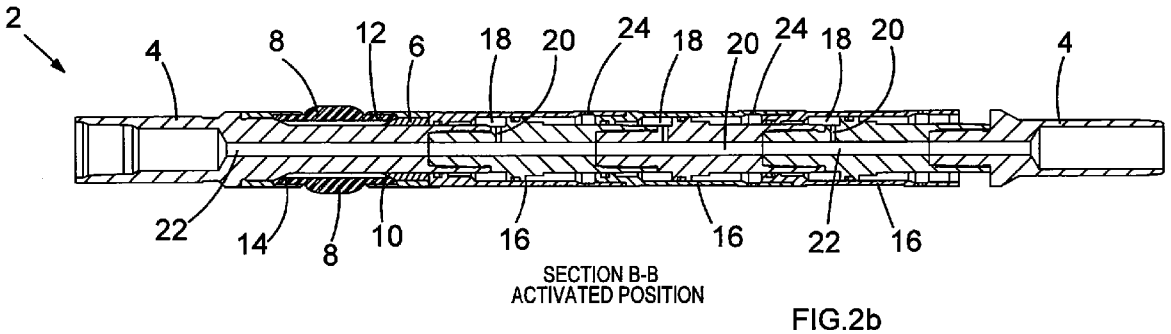


FIG.2b

(57) **Abstract:** An apparatus (2) for expanding wellbore casing comprises a body (4) configured to be located in casing disposed in a wellbore and an activation member (6) moveable relative to the body (4). A plurality of rigid deformation elements (8) is disposed around the body (4). The rigid deformation elements (8) have an inwardly retracted condition and an outwardly deployed working condition in which movement of the activation member (6) relative to the body (8) causes each said rigid deformation element (8) to move outwardly relative to the body (4) to come into contact with casing in which the apparatus is disposed to deform the casing by expansion.

WO 2018/007780 A1

Method and Apparatus for Expanding Wellbore Casing

The present invention relates to an apparatus for expanding wellbore casing and relates particularly, but not exclusively, to an apparatus for expanding and deforming a casing element against the sides of a wellbore to form an annular seal. The present invention also relates to a method of providing an annular seal in a wellbore by expanding and deforming a casing element comprising an elastomeric sleeve against the sides of the wellbore using an expandable downhole tool. Furthermore, the present invention relates to a tubular casing element comprising an elastomeric sleeve arranged to be deformed to provide an annular seal in a wellbore.

During the production of hydrocarbons from wellbores, in many circumstances it is desirable to isolate water or production zones of the wellbore or isolate zones to enable gas shut-off, acidizing, selective simulation and plug and abandonment.

For example, during the completion procedure, once an open wellbore has been lined with casing, the wellbore can be compartmentalised by providing a series of annular seals in the annulus between the casing and the surface of the wellbore. Compartmentalisation/zonal isolation enables greater control over hydrocarbon production. If one of the isolated zones produces large amounts of water, that zone can be shut off by use of an inflow control device (ICD) whilst the remaining zones defined by the respective annular seals continue to produce.

Known methods of providing annular wellbore seals for such zonal isolation procedures include using polymeric or soft alloy expandable packer elements mounted onto or between

lengths of casing. The expandable packer elements are inflated against the wellbore by using high downhole pressures.

This method suffers from the drawback that assembling casing incorporating such expandable packer elements increases cost and complexity of completion operation. The packer elements can also provide weak points in the casing prone to rupture and also a risk that the zonal isolation procedure will be incomplete if the packer fails to inflate and seal correctly.

Alternatively, swell packers mountable to the outside of casing can be used which react with wellbore fluid to swell in the annulus between the casing and the wellbore to provide a seal.

This method can suffer from the drawback that the swell packers take several days to form a seal which can be a costly delay in the production process. Also, if a swell packer fails to seal correctly, the zonal isolation process is incomplete and difficult to correct.

Preferred embodiments of the present invention seek to overcome the above disadvantages of the prior art.

According to an aspect of the present invention, there is provided an apparatus for expanding wellbore casing, the apparatus comprising:

a body configured to be located in casing disposed in a wellbore;

an activation member moveable relative to the body; and

a plurality of rigid deformation elements disposed around the body, said plurality of rigid deformation elements having an inwardly retracted condition and an outwardly deployed working condition in which movement of the activation member relative to the body causes each said rigid deformation element to move outwardly relative to the body to come into contact with casing in which the apparatus is disposed to deform the casing by expansion.

This provides the advantage of an apparatus that can be used to form annular seals in casing or tubulars already present in a wellbore. The apparatus can be located at a point in a wellbore where an annular seal is required, for example to provide zonal isolation, and operated to expand the casing outwardly against the wellbore at a particular point to form a seal. The apparatus can then be moved along the wellbore to form another seal or retrieved to the surface and re-used.

This therefore provides the advantage that the annular sealing apparatus does not have to be pre-installed in casing and left in the wellbore. This also provides the advantage of a highly reliable sealing method.

In a preferred embodiment, when in the retracted condition, said plurality of rigid deformation elements defines a continuous outer surface.

This provides the advantage of improving the reliability of the apparatus by reducing the likelihood of debris becoming lodged in between the rigid deformation elements. This therefore facilitates movement of the apparatus through casing.

Said continuous outer surface may define at least one circle.

Said continuous outer surface may be at least partially cylindrical.

In a preferred embodiment, each said rigid deformation element defines a part of a sector of a circle.

This provides the advantage of improving the reliability of the apparatus by facilitating retraction of the rigid deformation elements.

In a preferred embodiment, said body comprises a first inclined surface and wherein said activation member is configured to move longitudinally along the body to slide a first end of each of said plurality of rigid deformation elements along said inclined surface to bias said plurality of rigid deformation elements outwardly.
This provides the advantage of a mechanism found to deploy the rigid deformation elements with sufficient force to deform casing.

A second end of each of said plurality of rigid deformation elements may be pivotally mounted to the activation member.

The apparatus may further comprise a second inclined surface disposed on the body and being configured to slidably engage a second end of each of said plurality of rigid deformation elements.

In a preferred embodiment, the apparatus further comprises a plurality of pistons arranged to move the activation member relative to the body, each said piston defining a respective

pressure chamber arranged to be filled with fluid in response to an increase in fluid pressure in the body to move each of the plurality of pistons relative to the body and cause the activation member to move relative to the body.

This provides the advantage of a mechanism for enabling sufficient force to be generated by pressurising fluid in the apparatus.

In a preferred embodiment, the body comprises a cylindrical member having an internal bore defining a longitudinal axis, and wherein each said piston is mountable concentrically to the body and defines a part of the outer housing of the apparatus mountable to another piston defining a further part of the outer housing of the apparatus; and

a plurality of ports formed in the body enable fluid to flow from the bore to each said pressure chamber.

This provides the advantage of enabling the number of pistons to be readily increased or decreased depending on the physical requirements of a particular operation to increase or reduce the amount of deformation force available. This modular construction of the apparatus therefore provides a highly versatile tool for use in many different applications.

In a preferred embodiment, each said pressure chamber defines an annular chamber arranged concentrically around the body.

Each said piston may comprise an annular pressure port to enable wellbore fluid to be exhausted from the apparatus during activation of the respective piston.

According to another aspect of the present invention, there is provided a method of expanding wellbore casing, the method comprising:

locating an apparatus as defined above in a portion of wellbore casing;

moving the activation member relative to the body to move the plurality of rigid deformation elements from the retracted condition to the deployed condition to contact and deform the casing outwardly.

This provides the advantage of a method of providing an annular seal in a wellbore which comprises deforming standard wellbore casing into contact with a wellbore surface. No swell packers or expandable packer casing elements are required which therefore significantly reduces the cost and complexity of zonal isolation/compartmentalisation of wellbores.

This also provides the advantage of increasing the reliability of annular wellbore seals because use of expandable packers and swell packers might fail to deploy correctly which can result in zonal isolation failure. On the other hand the apparatus can be located and operated at a pre-determined pressure with accuracy.

In a preferred embodiment, the step of locating the apparatus in a portion of wellbore casing comprises locating said apparatus inside a tubular casing element comprising an elastomeric sealing element; and

wherein the step of moving the plurality of rigid deformation elements to the deployed condition to contact and deform the

casing outwardly compresses said elastomeric sealing element against the side of said wellbore to create an annular seal.

This provides the advantage of significantly increasing the reliability of the seal provided.

According to a further aspect of the present invention, there is provided a tubular casing element for a wellbore comprising an elastomeric sleeve disposed thereon.

This provides the advantage of a casing element that can be used to provide a reliable annular seal in the annulus between casing and the surface of a wellbore. Such a casing element is particularly advantageous because it is low cost and based on a very straightforward modification of existing casing elements.

According to a further aspect of the present invention, there is provided an assembly comprising a tubular casing element as defined above and an apparatus as defined above.

According to yet a further aspect of the present invention, there is provided a method of providing an annular seal in a wellbore, the method comprising:

locating a deformation apparatus comprising:

a body arranged to be disposed in a wellbore;

an activation member mounted to the body, wherein the activation member is moveable relative to the body from an unset condition to deform an elastomeric deformation element outwardly relative to the body; and

a plurality of pistons arranged to move the activation member relative to the body, each said piston defining a respective pressure chamber arranged to be filled with fluid in response to an increase in fluid pressure in the body to move each of the plurality of pistons relative to the body and cause the activation member to move relative to the body; and

wherein the step of activating the deformation apparatus to deploy said deformation member to deform said tubular casing element outwardly and compress said elastomeric sealing element against said wellbore comprises increasing fluid pressure in the body;

inside a tubular casing element comprising an elastomeric sealing element disposed in a wellbore; and

activating the deformation apparatus to deploy said deformation member to deform said tubular casing element outwardly and compress said elastomeric sealing element against the side of said wellbore to create an annular seal.

This provides the advantage of a method of providing an annular seal in a wellbore which comprises deforming standard wellbore casing into contact with a wellbore surface. No swell packers or expandable packer casing elements are required which significantly reduces cost and complexity of zonal isolation/compartmentalisation of wellbores.

This also provides the advantage of increasing the reliability of annular wellbore seals because use of expandable packers can form weak points in casing and both expandable packers and

swell packers might fail to deploy correctly which can result in zonal isolation failure. On the other hand, the deformation apparatus can be located and operated at a predetermined pressure with accuracy.

By providing an elastomeric sealing element around the standard casing, this provides the advantage of significantly increasing the reliability of the seal provided.

Furthermore, this provides the advantage that the method uses an apparatus that is modular in nature and therefore adjustable to provide a particular pressure required for particular casing size and wellbore conditions. In other words, by increasing or reducing the number of pistons used to deploy the activation member, the deployment pressure and therefore the force provided to deform the casing can be accurately controlled.

Moreover, this provides the advantage of reducing the cost of providing annular seals in wellbores for zonal isolation/compartmentalisation by providing a reusable deformation tool.

In a preferred embodiment, the method further comprises reducing fluid pressure in the body to cause the elastomeric deformation element to return the activation member to the unset condition to enable the deformation apparatus to be moved.

This provides the advantage of reducing operational complexity. All an operator has to do to deactivate the deformation apparatus is to reduce fluid pressure in the wellbore which enables the elastomeric deformation element to move to the un-deformed condition and push the activation

member back to the unset condition. This enables very straightforward repositioning of the deformation apparatus in the casing to enable movement between locations requiring casing deformation and annular sealing.

According to another aspect of the present invention, there is provided an assembly comprising a tubular casing element as defined above and a deformation apparatus comprising:

a body arranged to be disposed in a wellbore;

an activation member mounted to the body, wherein the activation member is moveable relative to the body from an unset condition to deform an elastomeric deformation element outwardly relative to the body; and

characterised by a plurality of pistons arranged to move the activation member relative to the body, each said piston defining a respective pressure chamber arranged to be filled with fluid in response to an increase in fluid pressure in the body to move each of the plurality of pistons relative to the body and cause the activation member to move relative to the body, wherein when fluid pressure is reduced in the body, the elastomeric deformation element returns the activation member to the unset condition.

This provides the advantage of an assembly which provides a low cost and easy to operate means of providing an annular seal in casing in a wellbore to enable zonal isolation.

Preferred embodiments of the present invention will now be described, by way of example only and not in any limitative sense, with reference to the accompanying drawings in which:

Figure 1a is a side view of an apparatus for expanding wellbore casing in accordance with a first embodiment of the present invention, wherein the apparatus is shown with the rigid deformation elements in the inwardly retracted condition;

Figure 1b is a cross section of the apparatus of Figure 1a;

Figure 2a is a side view of the apparatus of Figures 1a and 1b showing the rigid deformation elements in the outwardly deployed working condition;

Figure 2b is a cross sectional view of Figure 2a;

Figure 3a is a side view of an apparatus for expanding wellbore casing in accordance with a second embodiment of the present invention in which the rigid deformation elements are shown in the inwardly retracted condition;

Figure 3b is a cross sectional view of Figure 3a;

Figure 4a is a side view of the apparatus of Figures 3a and 3b showing the rigid deformation elements in the outwardly deployed working condition;

Figure 4b is a cross sectional view corresponding to Figure 4a;

Figure 5 is a side view of a tubular casing element of a third embodiment of the present invention;

Figure 6 is a side view of a Bottom Hole Assembly (BHA) incorporating the apparatus for expanding wellbore casing of Figures 3 and 4;

Figure 7a is a side view of an assembly of the tubular casing element of Figure 5 and the Bottom Hole Assembly of Figure 6 shown with the ridged deformation elements in the retracted condition;

Figure 7b is a view corresponding to Figure 7a showing the rigid deformation elements in the deployed condition to deform the tubular casing element and form an annular seal in a wellbore; and

Figure 8 is a side view of a Bottom Hole Assembly (BHA) incorporating a deformation apparatus used in a method of providing an annular seal in a wellbore according to another embodiment of the present invention;

Figure 9a is a cross-sectional view of an assembly of the tubular casing element of Figure 5 and the BHA of Figure 8 located downhole in a wellbore;

Figure 9b is a cross-sectional view of the assembly of Figure 9a showing the deformation apparatus and deformation member expanded outwardly to deform the tubular casing to provide an annular seal in the wellbore;

Figure 10a is a cross-sectional view of the deformation apparatus of Figure 8 in the unset condition; and

Figure 10b is a cross-sectional view of the deformation apparatus of Figure 10a in the set condition.

Referring to Figures 1a, 1b, 2a and 2b, an apparatus 2 for expanding wellbore casing comprises a body 4 configured to be located in casing (not shown) disposed in a wellbore and an activation member 6 moveable relative to the body 4. A plurality of rigid deformation elements 8 is disposed around the body 4. The rigid deformation elements 8 have an inwardly retracted condition as shown in Figures 1a and 1b and an outwardly deployed working condition as shown in Figures 2a and 2b in which movement of the activation member 6 relative to the body 8 (in the direction left to right in the drawings) causes each said rigid deformation element 8 to move outwardly relative to the body 4 to come into contact with casing in which the apparatus is disposed to deform the casing by expansion.

In the retracted condition, the rigid deformation elements 8 define a continuous outer surface which is part cylindrical and does not extend past the outer extent of body 4. The rigid deformation elements 8 also each define part of a sector of a circle and therefore define at least one circle on the outer surface in the retracted condition. This ensures that debris is less likely to become lodged between the individual elements during movement along the wellbore in the retracted condition.

The activation member 6 comprises a first inclined surface 10 arranged to slide under a first end 12 of each said rigid deformation element during activation. The body 4 also comprises a second inclined surface 14 arranged adjacent a second end of each rigid deformation element 8 such that when the activation member 6 moves along the body, first inclined

surface 10 slides under first end 12 of each rigid deformation element 8 which pushes the rigid deformation element 8 up along second inclined surface 14 to move the rigid deformation elements 8 outwardly.

To enable movement of the activation member 6 along the body, a plurality of pistons 16 are arranged in abutment with the activation member 6. Each piston 16 defines a pressure chamber 18 in fluid communication with a longitudinal bore 22 along the centre of the apparatus via ports 20.

When fluid is pumped along bore 22, an increase in pressure in chambers 18 causes annular fluid to be exhausted through annular ports 24 and at the same time move pistons 6 (from right to left in the drawings). This in turn pushes activation member 6 along the body 4 and first inclined surface 10 under first ends 12 of each rigid deformation element to move the elements 8 outwardly. This force is then transferred outwardly against the casing or tubular in which the apparatus is disposed and as a result of multiple piston chambers 18, the force is sufficient to continue expansion of the casing or tubular beyond its yield point into the plastic deformation range in order to create an annular seal of casing against the side of a wellbore. The casing or tubular to be deformed can be provided with an elastomeric outer sleeve to improve sealing.

When fluid pressure is reduced, pulling the apparatus along the wellbore enables the deformation elements 8 to retract into the body. Rigid deformation elements 8 are preferably formed from steel, although other rigid materials could be used.

Referring to Figures 3a, 3b, 4a and 4b a second embodiment of the apparatus 32 has many parts common with the first embodiment 2, in particular the means for moving activation member 36 along body 34 by multiple stacked pistons 46 is identical to the first embodiment such that the pistons will not be described in any further detail herein.

In the second embodiment, each rigid deformation element 38 has a second end 39 which is pivotally interconnected in a corresponding recess 41 in the activation member 36. As a result, when activation member 36 moves along the body, each rigid deformation element 38 is slid along inclined surface 14causing the elements to pivot outwardly as shown in Figures 4a and 4b. This configuration ensured that pulling on the work string ensures that the rigid deformation elements 38 unset.

Depending on the particular geometry of the annular seals required and the force required, an operator can choose between either the first or second embodiment. The modular nature of pistons 16 and 46 also enable further pistons to be mounted on the body or the number of pistons reduced as required to enable control of the force required.

Referring to Figure 5, a tubular casing element 50 comprises a standard length of steel casing 54 onto which an elastomeric sleeve 56 is mounted. Steel casing 54 is generally used to line and complete open wellbores. Elastomeric sleeve 56 is formed from elastomeric material such as rubber and mounted onto the casing element 54 by means of an adhesive such as an epoxy. A centralising element 58 is also provided to centralise the casing element 50 when placed downhole in a wellbore. Casing, 52 having an internal thread (not shown) is

threated onto casing 54 to enable interconnection to other lengths of casing.

Referring to Figures 6, 7a and 7b, a bottom hole assembly (BHA) 60 is an assembly comprising deformation apparatus 32, a bull nose 62 and a casing collar locator 64. The BHA 60 can be deployed down a wellbore on coil tubing 68 or a similar means which will be familiar to persons skilled in the art. Casing collar locator 64 comprises a plurality of detent elements 66 which are biased outwardly and are slidable along the internal surface of tubular casing 54 until the joint between two lengths of casing at collar 52 is located.

The operation of apparatus 32 to provide an annular seal in a wellbore will now be described with reference to Figures 7a and 7b.

An open borehole known as a wellbore 51 is lined with multiple tubular casing elements 50. BHA 60 is then moved into the casing elements 50 located in wellbore 51. The bottom of the wellbore 51 is tagged by bull nose 62 and the apparatus 32 is then slowly pulled up through the wellbore until the outwardly biased detents 66 of the casing collar locator 64 locate casing collar 52. At this stage, the BHA 60 is held in position.

A predetermined fluid pressure is applied by pumps on the surface to the inner diameter 42 (Figures 3b and 4b) of apparatus 32 and held for a predetermined length of time. This cases rigid deformation elements 38 to deploy as explained above, and therefore to contact the inner surface of tubular casing element 54 in the region of elastomeric element 56 and deform the tubular casing element 54 outwardly. This pushes

the elastomeric sealing element 56 against the surface of wellbore 51 to create an annular seal 70.

Although only a single deformation apparatus 32 is shown in Figures 7a and 7b, it is preferable to run two apparatuses 32 at the same time, one below the casing collar locator 64 and one above to form two annular seals 70 at the same time and therefore form a compartmentalised length of casing in a single operation.

An advantage of operating multiple apparatus 32 in this manner is that the seals formed prevent casing collar leakage because the elastomeric seal elements 56 above and below the casing collar 52 prevent wellbore fluid reaching the casing collar 52. Furthermore, multiple sets of deformation apparatuses 32 can be run at the same time in a single work string to form any number of annular seals 70 at the same time. This greatly reduces cost and the amount of time taken to compartmentalise wellbores.

Referring to Figure 8, a deformation apparatus 110 used in a further embodiment of the invention comprises a body 112 and an elastomeric deformation element 114 outwardly moveable under compression relative to the body. The deformation apparatus 110 is mountable in a BHA 160 comprising a bull nose 116 and casing collar locator 118. The deformation apparatus can be deployed on coil tubing 122 or other methods which will be familiar to persons skilled in the art. Casing collar locator 118 comprises a plurality of detent elements 120 biased outwardly from the body and being slidable along the internal surface of the tubular casing element 50 (Figure 5) until it locates the joint between two lengths of casing at casing collar 52.

The operation of an assembly of tubular casing element 50 and deformation apparatus 110 to provide an annular seal in a wellbore will now be described with referenced to Figures 9a and 9b.

Firstly, the tubular casing element 50 is assembled comprising a standard length of tubular steel casing 54 onto which the elastomeric sealing element 56, centralising element 58 and casing collar 52 are mounted. The tubular casing element 50 is then run into a wellbore 111 in a standard completion procedure to line wellbore 111.

A bottom hole assembly (BHA) 160 comprising the deformation apparatus 110 is then run into the wellbore 111 on coil tubing 122 (or another suitable means). The bottom of the wellbore is tagged and the deformation apparatus 110 is then slowly pulled up through the wellbore until the outwardly biased detents 120 of the casing collar locator 118 locate casing collar 52. The deformation apparatus 110 is then held in position.

At this point, a predetermined fluid pressure is applied by pumps on the surface to the inner diameter of deformation apparatus 110 and held for a predetermined length of time. This causes activation member 126 of the deformation apparatus 110 to move along body 112 and compress and deform the elastomeric deformation member 114 outwardly. The deformation member 114 contacts tubular casing 54 and pushes with sufficient force to deform the steel and form an annular deformation 128 in the casing. This pushes the elastomeric sealing element 56 against the surface of the wellbore 111.

This forms an annular seal to isolate sections 111a and 111b of wellbore 111.

Although only a single deformation apparatus 10 is shown in Figures 9a and 9b, it is preferable to run two deformation apparatuses at the same time, one below the casing collar locator 118 as shown in Figures 9a and 9b and one above (not shown) to form two annular casing deformations 128 at the same time and therefore form a casing compartment in a single operation. The second annular casing deformation would therefore be located at the top of annular wellbore section 111a.

An advantage of operating deformation apparatuses 110 in this manner is that the seals formed prevent casing collar leakage because the elastomeric seal elements 56 above and below the casing collar 52 prevent wellbore fluid reaching the casing collar 52. Furthermore, multiple sets of deformation apparatus 110 can be run at the same time in a single work string to form any number of annular seals 128 at the same time which greatly reduces cost and the amount of time taken to conduct a zonal isolation operation.

Once the annular seals 128 are formed, reducing fluid pressure in the deformation apparatuses 110 causes un-setting by enabling the elastomeric deformation member 114 to push the activation member 126 back along body 112 from the position shown in Figure 9b to that of Figure 9a. The deformation apparatuses 110 can then be moved up to another casing joint if required to repeat the process to provide further annular seals.

Referring to Figures 10a and 10b, the deformation apparatus 110 comprises a body 112 and an activation member 126 mounted to the body. The activation member is slideable along the body 112 from an unset condition to deform the elastomeric deformation element 114 outwardly as shown in Figure 4b. A plurality of internal ports 130 are provided in body 112 to enable fluid to flow into concentric piston chambers 132. A plurality of annular ports 134 are provided to provide a fluid exhaust. When fluid pressure is increased in the body 112, fluid flows under dynamic pressure through ports 130 into piston chambers 132. This pushes activation member 126 along the body to compress and deform the elastomeric deformation element 114 outwardly.

The elasticity of element 114 may be sufficient such that when fluid pressure is reduced below a predetermined level, the elastomeric deformation element 114 pushes activation member 126 back along the body from the condition shown in Figure 10b to the unset condition of Figure 10a. The expandable tools and elastomeric sleeves disclosed herein could be used to seal the overlap of a liner.

It will be appreciated by persons skilled in the art that the above embodiments have been described by way of example only and not in any limitative sense, and that various alterations and modifications are possible without departure from the scope of the invention as defined by the appended claims.

Claims

1. An apparatus for expanding wellbore casing, the apparatus comprising:

a body configured to be located in casing disposed in a wellbore;

an activation member moveable relative to the body; and

a plurality of rigid deformation elements disposed around the body, said plurality of rigid deformation elements having an inwardly retracted condition and an outwardly deployed working condition in which movement of the activation member relative to the body causes each said rigid deformation element to move outwardly relative to the body to come into contact with casing in which the apparatus is disposed to deform the casing by expansion.

2. An apparatus according to claim 1, wherein when in the retracted condition, said plurality of rigid deformation elements defines a continuous outer surface.

3. An apparatus according to claim 2, wherein said continuous outer surface defines at least one circle.

4. An apparatus according to claim 2 or 3, wherein said continuous outer surface is at least partially cylindrical.

5. An apparatus according to any one of the preceding claims, wherein each said rigid deformation element defines a part of a sector of a circle.

6. An apparatus according to any one of the preceding claims, wherein said body comprises a first inclined surface and wherein said activation member is configured to move longitudinally along the body to slide a first end of each of said plurality of rigid deformation elements along said inclined surface to bias said plurality of rigid deformation elements outwardly.

7. An apparatus according to claim 6, wherein a second end of each of said plurality of rigid deformation elements is pivotally mounted to the activation member.

8. An apparatus according to claim 6, further comprising a second inclined surface disposed on the body and being configured to slidably engage a second end of each of said plurality of rigid deformation elements.

9. An apparatus according to any one of the preceding claims, further comprising a plurality of pistons arranged to move the activation member relative to the body, each said piston defining a respective pressure chamber arranged to be filled with fluid in response to an increase in fluid pressure in the body to move each of the plurality of pistons relative to the body and cause the activation member to move relative to the body.

10. An apparatus according to claim 9, wherein the body comprises a cylindrical member having an internal bore defining a longitudinal axis, and wherein each said piston is mountable concentrically to the body and defines a part of the outer housing of the apparatus mountable to another piston defining a further part of the outer housing of the apparatus; and

a plurality of ports formed in the body enable fluid to flow from the bore to each said pressure chamber.

11. An apparatus according to claim 9 or 10, wherein each said pressure chamber defines an annular chamber arranged concentrically around the body.

12. An apparatus according to any one of claims 9 to 11, wherein each said piston comprises an annular pressure port to enable wellbore fluid to be exhausted from the apparatus during activation of the respective piston.

13. A method of expanding wellbore casing to provide an annular seal in a wellbore, the method comprising:

locating an apparatus according to any one of the preceding claims in a portion of wellbore casing;

moving the activation member relative to the body to move the plurality of rigid deformation elements from the retracted condition to the deployed condition to contact and deform the casing outwardly.

14. A method according to claim 13, wherein the step of locating the apparatus in a portion of wellbore casing comprises locating said apparatus inside a tubular casing element comprising an elastomeric sealing element; and

wherein the step of moving the plurality of rigid deformation elements to the deployed condition to contact and deform the casing outwardly compresses said elastomeric sealing element against the side of said wellbore to create an annular seal.

15. A tubular casing element for a wellbore comprising an elastomeric sleeve disposed thereon.

16. An assembly comprising a tubular casing element according to claim 15 and an apparatus according to any one of claims 1 to 12.

17. A method of providing an annular seal in a wellbore, the method comprising:

locating a deformation apparatus comprising:

a body arranged to be disposed in a wellbore;

an activation member mounted to the body, wherein the activation member is moveable relative to the body from an unset condition to deform an elastomeric deformation element outwardly relative to the body; and

a plurality of pistons arranged to move the activation member relative to the body, each said piston defining a respective pressure chamber arranged to be filled with fluid in response to an increase in fluid pressure in the body to move each of the plurality of pistons relative to the body and cause the activation member to move relative to the body; and

wherein the step of activating the deformation apparatus to deploy said deformation member to deform said tubular casing element outwardly and compress said

elastomeric sealing element against said wellbore comprises increasing fluid pressure in the body;

inside a tubular casing element comprising an elastomeric sealing element disposed in a wellbore; and

activating the deformation apparatus to deploy said deformation member to deform said tubular casing element outwardly and compress said elastomeric sealing element against the side of said wellbore to create an annular seal.

18. A method according to claim 17, further comprising reducing fluid pressure in the body to cause the elastomeric deformation element to return the activation member to the unset condition to enable the deformation apparatus to be moved.

19. An assembly comprising a tubular casing element according to claim 15 and a deformation apparatus comprising:

a body arranged to be disposed in a wellbore;

an activation member mounted to the body, wherein the activation member is moveable relative to the body from an unset condition to deform an elastomeric deformation element outwardly relative to the body; and

characterised by a plurality of pistons arranged to move the activation member relative to the body, each said piston defining a respective pressure chamber arranged to be filled with fluid in response to an increase in fluid pressure in the body to move each of the plurality of pistons relative to the body and cause the activation member to move relative to

the body, wherein when fluid pressure is reduced in the body, the elastomeric deformation element returns the activation member to the unset condition.

AMENDED CLAIMS
received by the International Bureau on
14 August 2017 (14.08.2017)

Claims

1. An apparatus for expanding wellbore casing, the apparatus comprising:

a body configured to be located in casing disposed in a wellbore;

an activation member moveable relative to the body;

a plurality of rigid deformation elements disposed around the body, said plurality of rigid deformation elements having an inwardly retracted condition and an outwardly deployed working condition in which movement of the activation member relative to the body causes each said rigid deformation element to move outwardly relative to the body to come into contact with casing in which the apparatus is disposed to deform the casing by expansion;

characterised in that the apparatus further comprises a plurality of pistons arranged to move the activation member relative to the body, each said piston defining a respective pressure chamber arranged to be filled with fluid in response to an increase in fluid pressure in the body to move each of the plurality of pistons relative to the body and cause the activation member to move relative to the body.

2. An apparatus according to claim 1, wherein when in the retracted condition, said plurality of rigid deformation elements defines a continuous outer surface.

3. An apparatus according to claim 2, wherein said continuous outer surface defines at least one circle.

4. An apparatus according to claim 2 or 3, wherein said continuous outer surface is at least partially cylindrical.

5. An apparatus according to any one of the preceding claims, wherein each said rigid deformation element defines a part of a sector of a circle.

6. An apparatus according to any one of the preceding claims, wherein said body comprises a first inclined surface and wherein said activation member is configured to move longitudinally along the body to slide a first end of each of said plurality of rigid deformation elements along said inclined surface to bias said plurality of rigid deformation elements outwardly.

7. An apparatus according to claim 6, wherein a second end of each of said plurality of rigid deformation elements is pivotally mounted to the activation member.

8. An apparatus according to claim 6, further comprising a second inclined surface disposed on the body and being configured to slidably engage a second end of each of said plurality of rigid deformation elements.

9. An apparatus according to any one of the preceding claims, wherein the body comprises a cylindrical member having an internal bore defining a longitudinal axis, and wherein each said piston is mountable concentrically to the body and defines a part of the outer housing of the apparatus mountable to another piston defining a further part of the outer housing of the apparatus; and

a plurality of ports formed in the body enable fluid to flow from the bore to each said pressure chamber.

10. An apparatus according to any one of the preceding claims, wherein each said pressure chamber defines an annular chamber arranged concentrically around the body.

11. An apparatus according to any one of the preceding claims, wherein each said piston comprises an annular pressure port to enable wellbore fluid to be exhausted from the apparatus during activation of the respective piston.

12. A method of expanding wellbore casing to provide an annular seal in a wellbore, the method comprising:

locating an apparatus according to any one of the preceding claims in a portion of wellbore casing;

moving the activation member relative to the body to move the plurality of rigid deformation elements from the retracted condition to the deployed condition to contact and deform the casing outwardly.

13. A method according to claim 12, wherein the step of locating the apparatus in a portion of wellbore casing comprises locating said apparatus inside a tubular casing element comprising an elastomeric sealing element; and

wherein the step of moving the plurality of rigid deformation elements to the deployed condition to contact and deform the casing outwardly compresses said elastomeric sealing element against the side of said wellbore to create an annular seal.

14. An assembly comprising:

a tubular casing element for a wellbore comprising an elastomeric sleeve disposed thereon ; and

an apparatus according to any one of claims 1 to 11.

15. A method of providing an annular seal in a wellbore, the method comprising:

locating a deformation apparatus comprising:

a body arranged to be disposed in a wellbore;

an activation member mounted to the body, wherein the activation member is moveable relative to the body from an unset condition to deform an elastomeric deformation element outwardly relative to the body; and

a plurality of pistons arranged to move the activation member relative to the body, each said piston defining a respective pressure chamber arranged to be filled with fluid in response to an increase in fluid pressure in the body to move each of the plurality of pistons relative to the body and cause the activation member to move relative to the body; and

wherein the step of activating the deformation apparatus to deploy said deformation member to deform said tubular casing element outwardly and compress said elastomeric sealing element against said wellbore comprises increasing fluid pressure in the body;

inside a tubular casing element comprising an elastomeric sealing element disposed in a wellbore; and

activating the deformation apparatus to deploy said deformation member to deform said tubular casing element outwardly and compress said elastomeric sealing element against the side of said wellbore to create an annular seal.

16. A method according to claim 15, further comprising reducing fluid pressure in the body to cause the elastomeric deformation element to return the activation member to the unset condition to enable the deformation apparatus to be moved.

17. An assembly comprising a tubular casing element for a wellbore comprising an elastomeric sleeve disposed thereon and a deformation apparatus comprising:

a body arranged to be disposed in a wellbore;

an activation member mounted to the body, wherein the activation member is moveable relative to the body from an unset condition to deform an elastomeric deformation element outwardly relative to the body; and

characterised by a plurality of pistons arranged to move the activation member relative to the body, each said piston defining a respective pressure chamber arranged to be filled with fluid in response to an increase in fluid pressure in the body to move each of the plurality of pistons relative to the body and cause the activation member to move relative to the body, wherein when fluid pressure is reduced in the body,

the elastomeric deformation element returns the activation member to the unset condition.

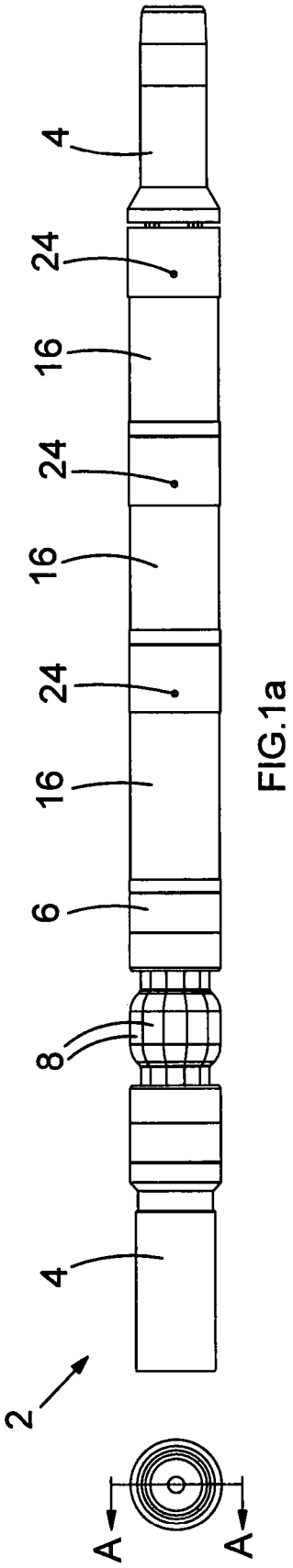
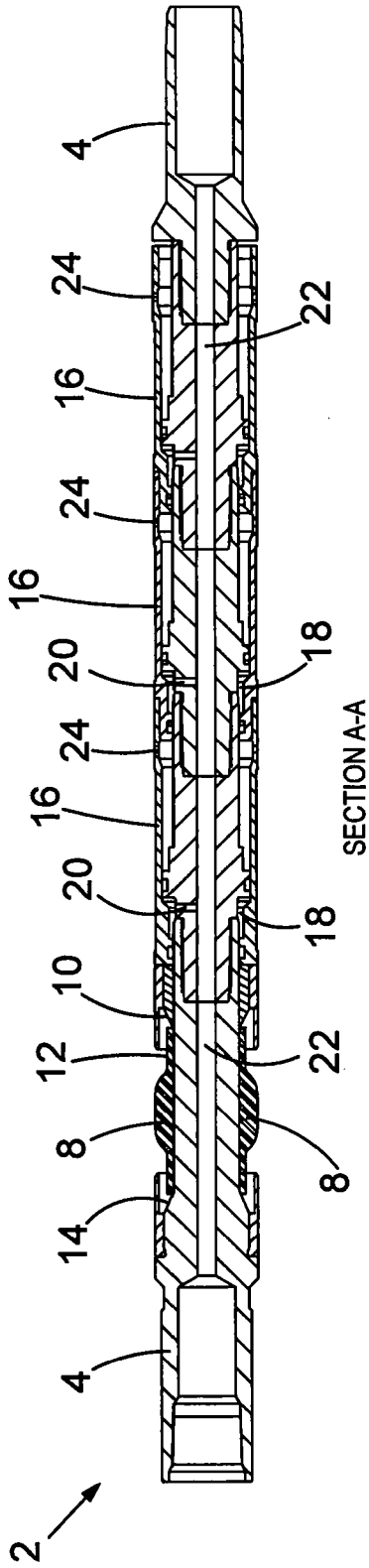


FIG.1a



SECTION A-A
RUN IN POSITION

FIG.1b

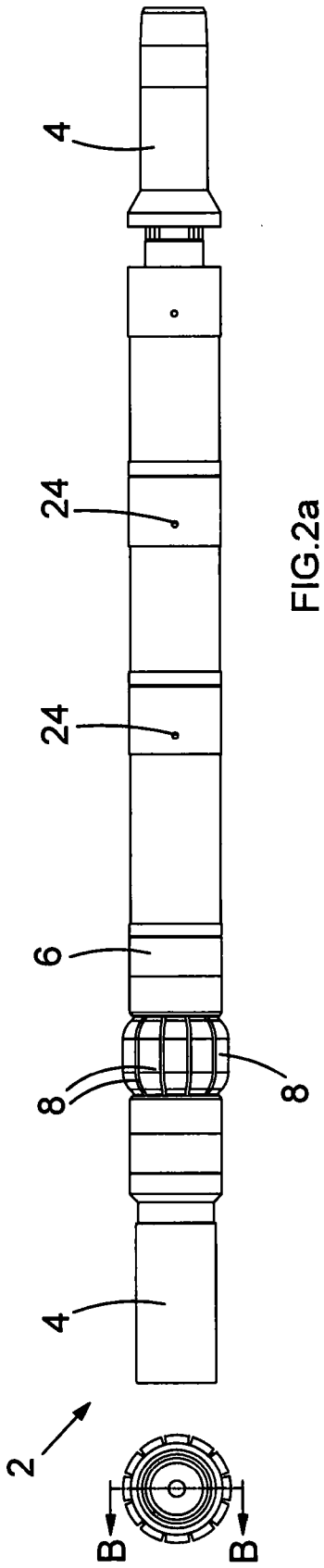
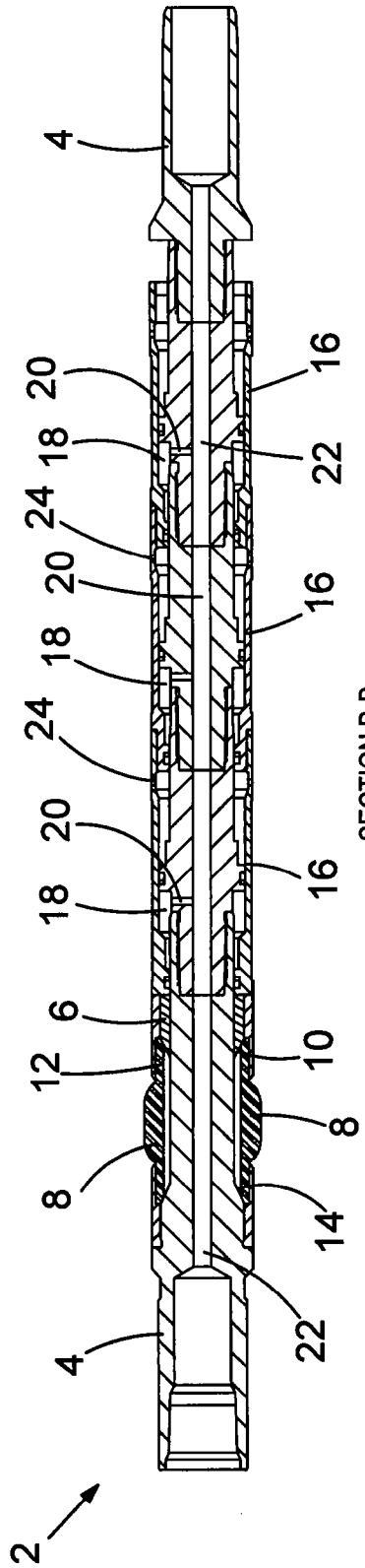


FIG.2a



SECTION B-B
ACTIVATED POSITION

FIG.2b

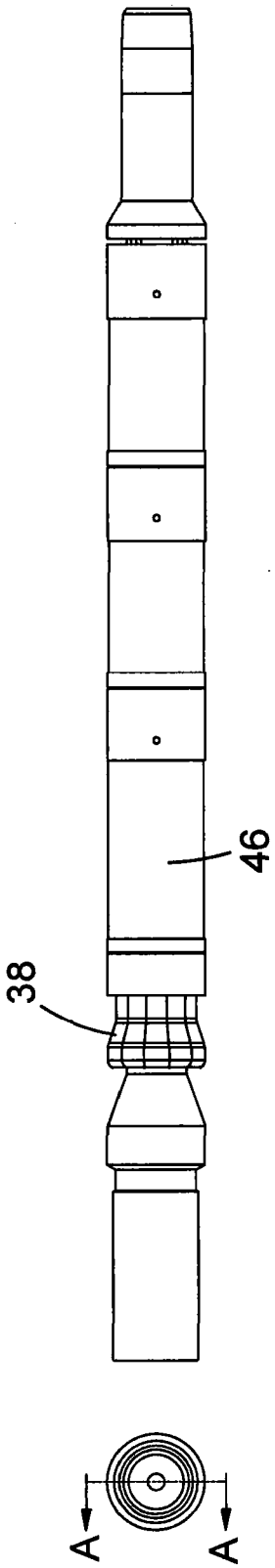
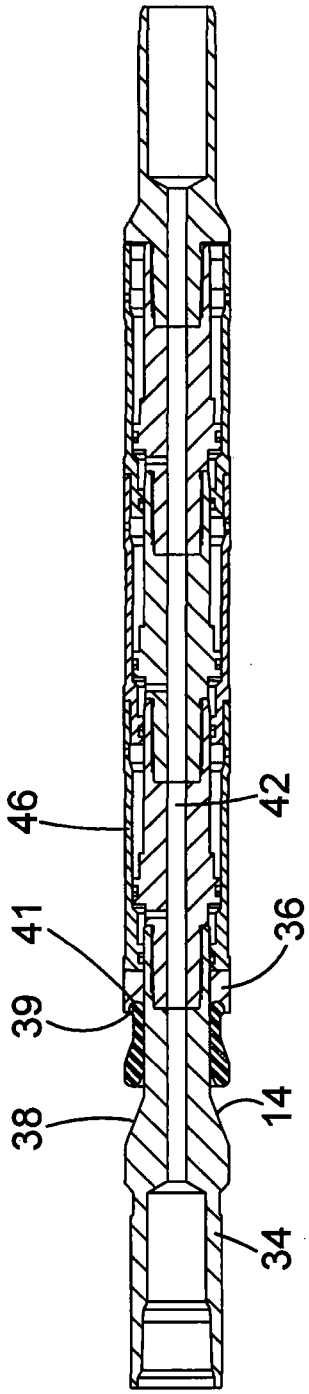


FIG.3a



SECTION A-A
RUN IN POSITION

FIG.3b

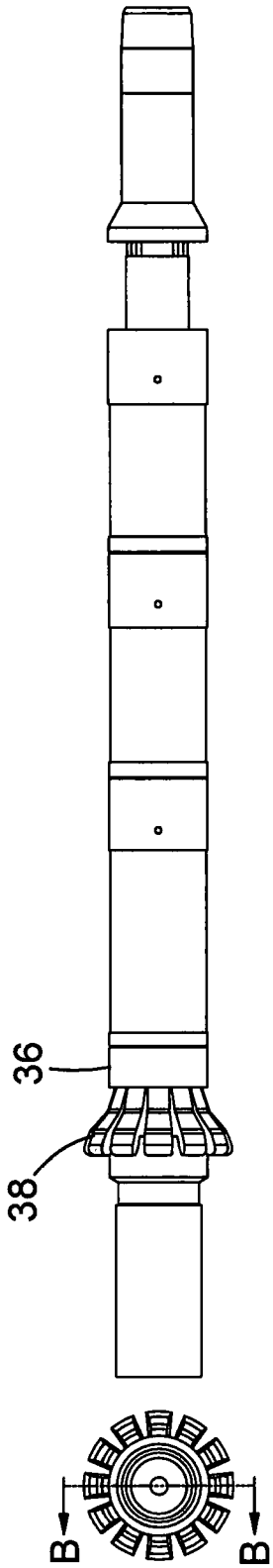


FIG.4a

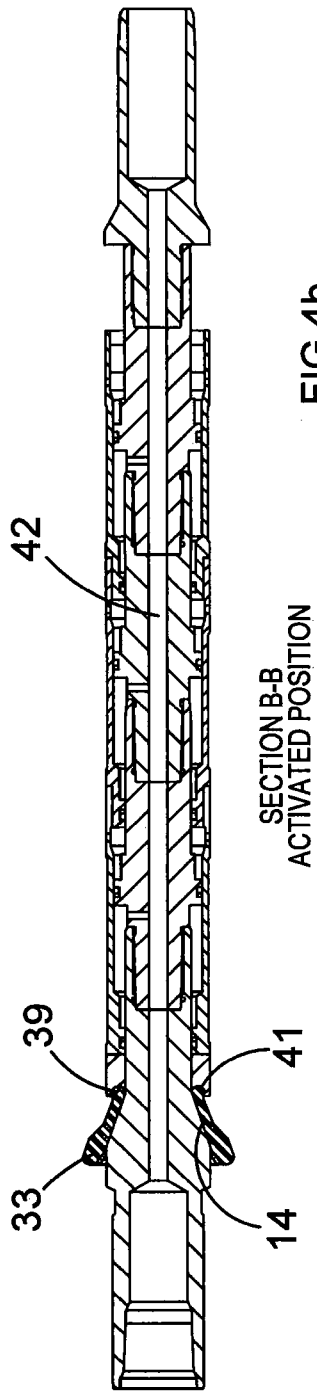


FIG.4b

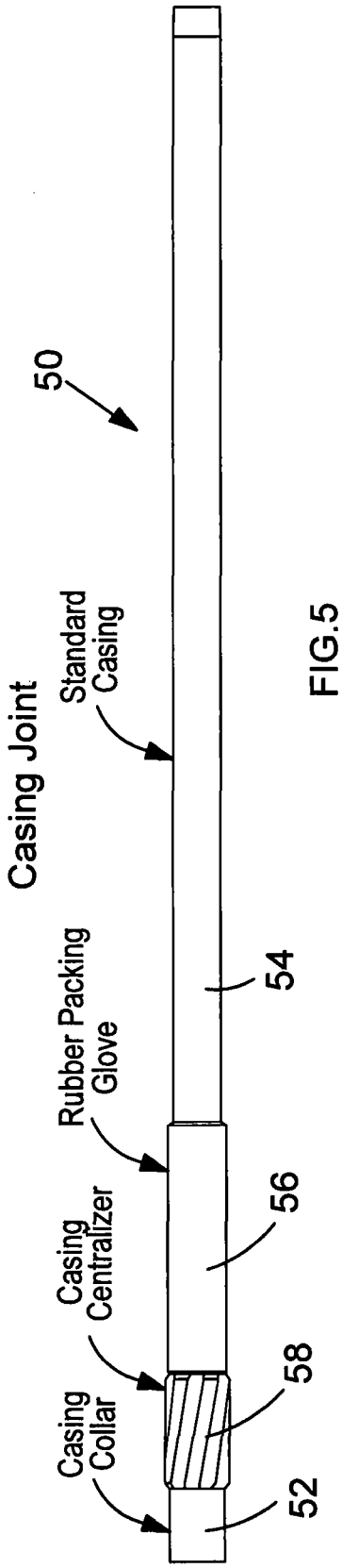

50
Casing Joint
Standard Casing
54
Rubber Packing Glove
56
Casing Centralizer
58
Casing Collar
52

FIG.5

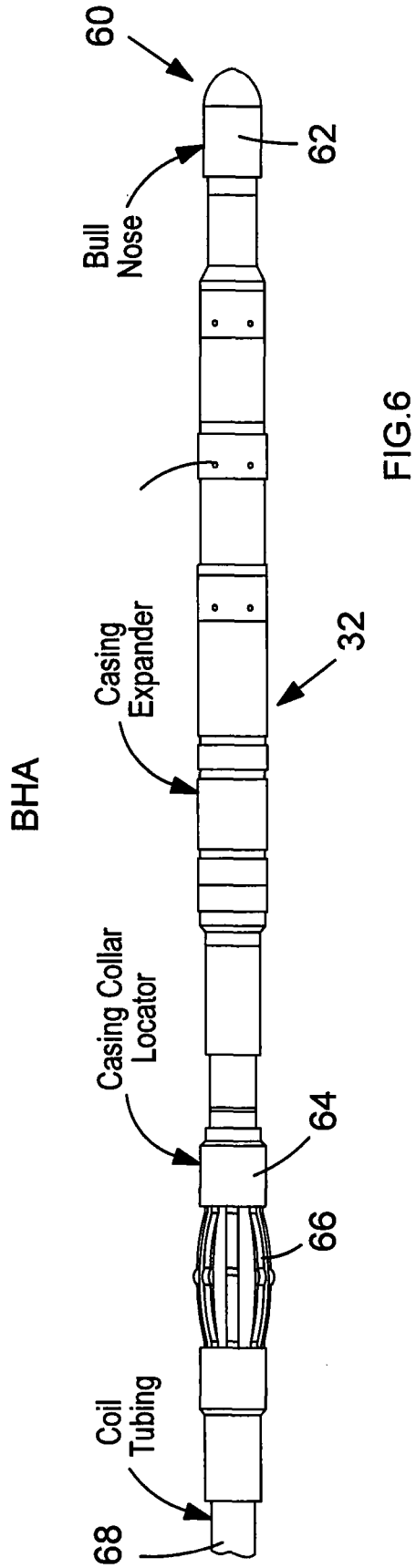

60
62
Bull Nose
32
BHA
Casing Expander
Casing Collar Locator
64
66
Coil Tubing
68

FIG.6

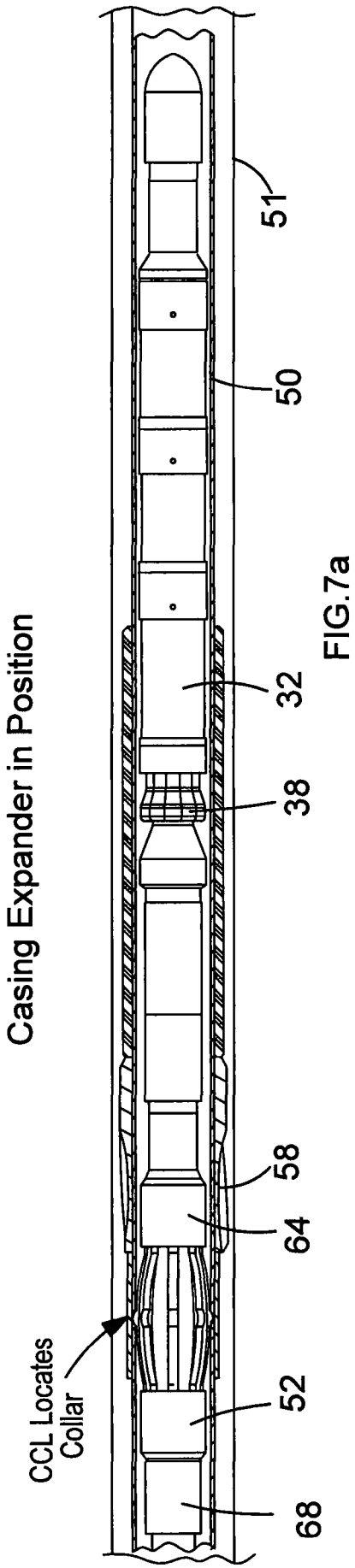

Casing Expander in Position
CCL Locates Collar
51
50
32
38
58
64
52
68

FIG.7a

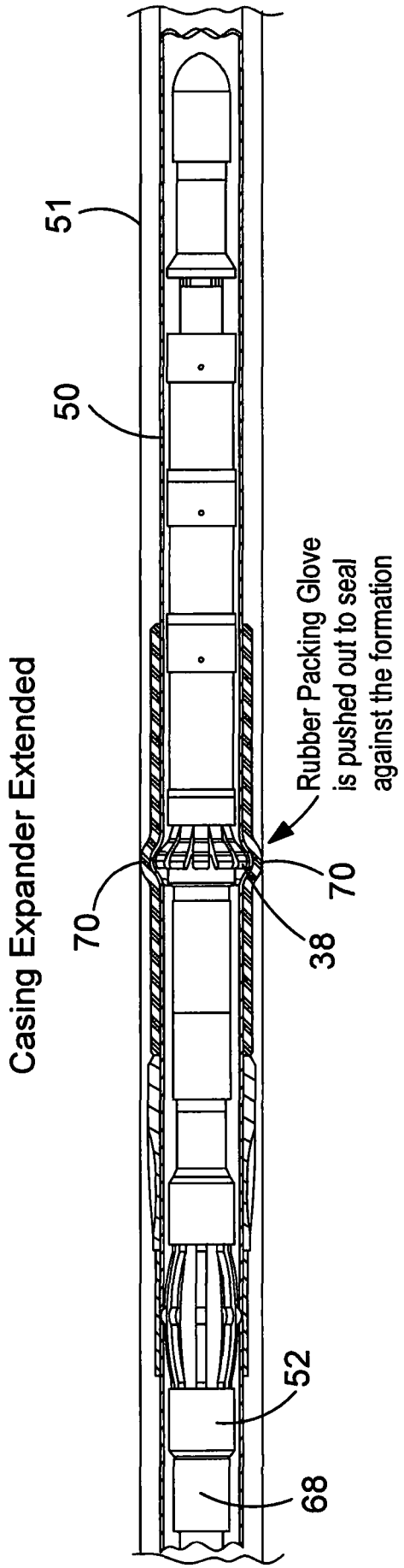

Casing Expander Extended
Rubber Packing Glove is pushed out to seal against the formation
51
50
70
70
38
52
68

FIG.7b

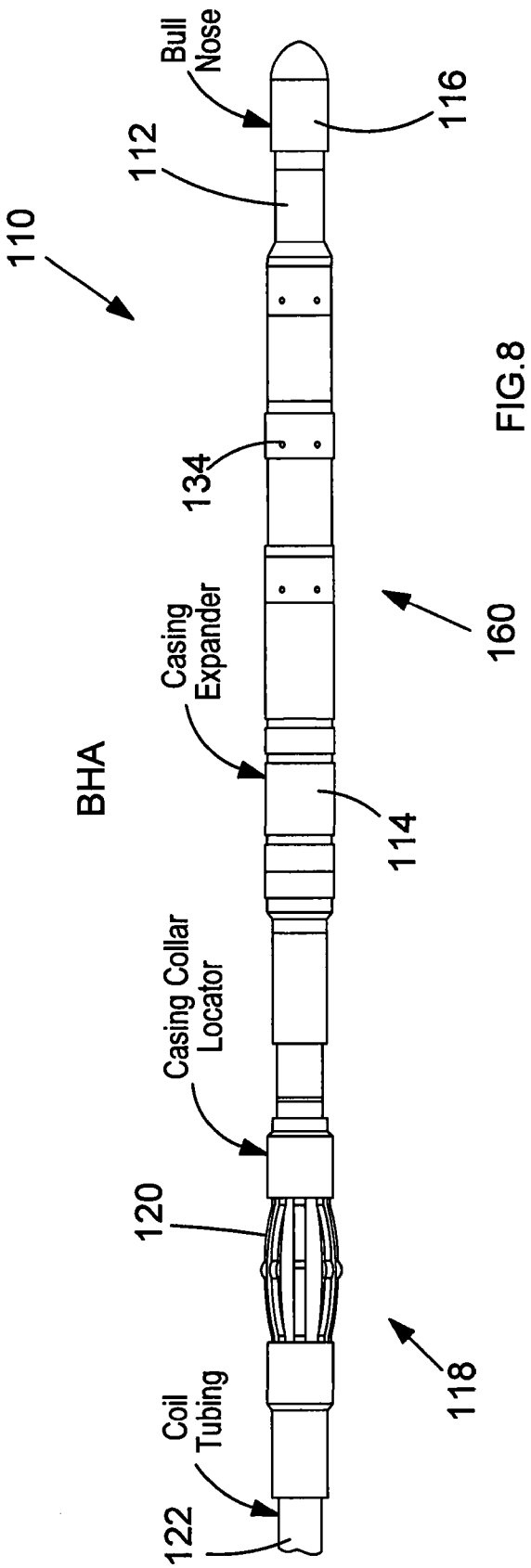

Bull Nose
116
112
110
134
Casing Expander
160
BHA
114
Casing Collar Locator
120
118
Coil Tubing
122

FIG.8

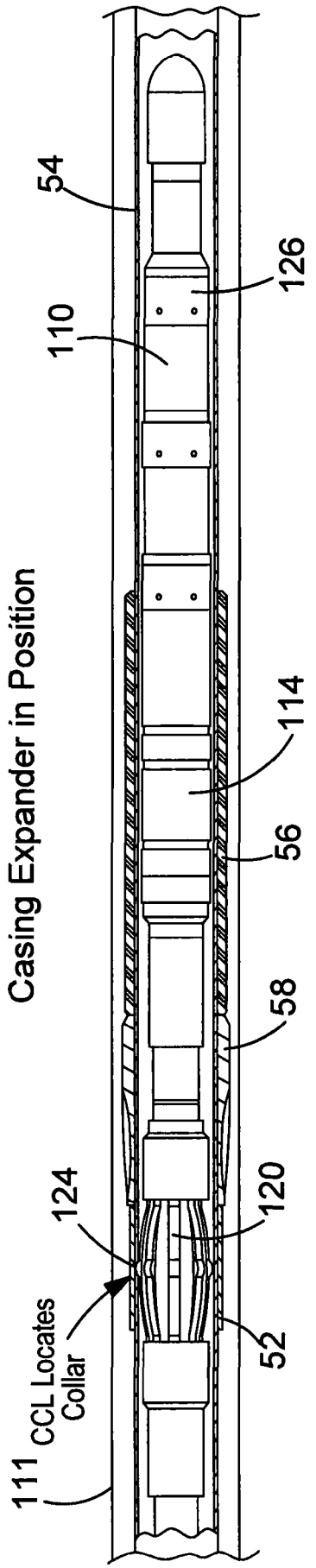

Casing Expander in Position
54
126
110
114
56
58
124
120
CCL Locates Collar
52
111

FIG.9a

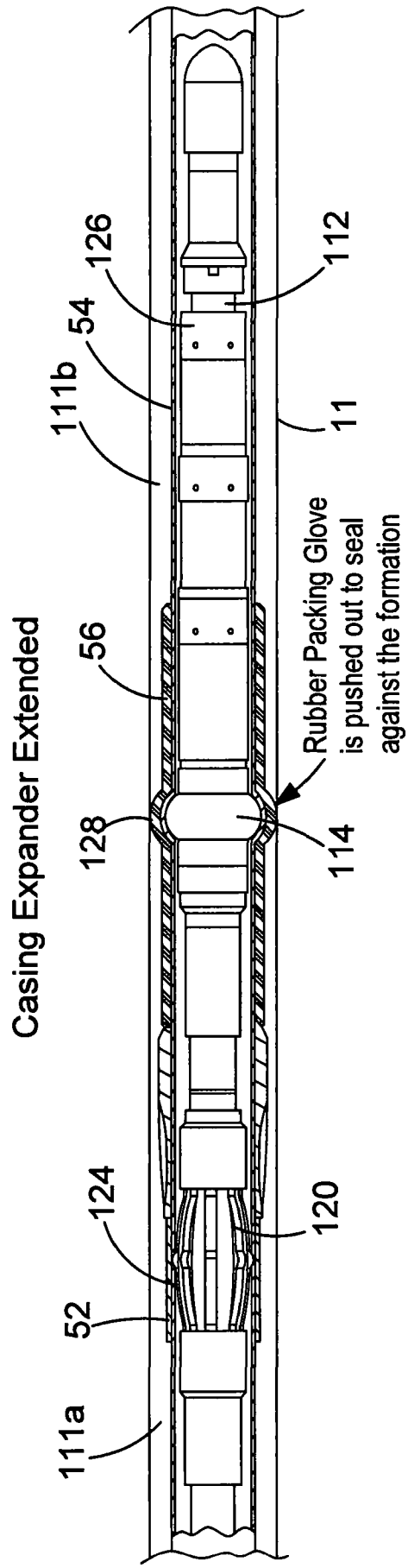

Casing Expander Extended
126
112
54
111b
11
56
Rubber Packing Glove is pushed out to seal against the formation
128
114
124
120
52
111a

FIG.9b

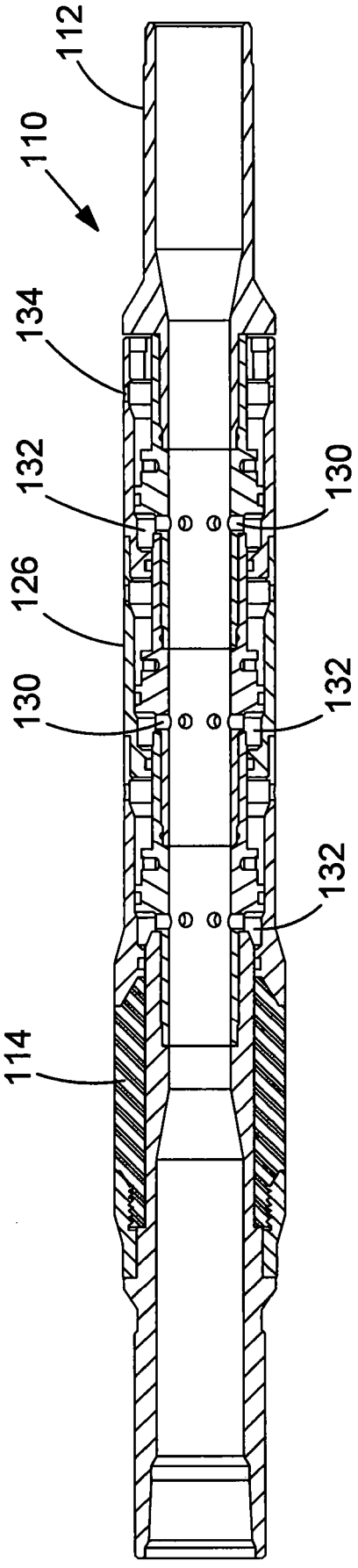


FIG.10a

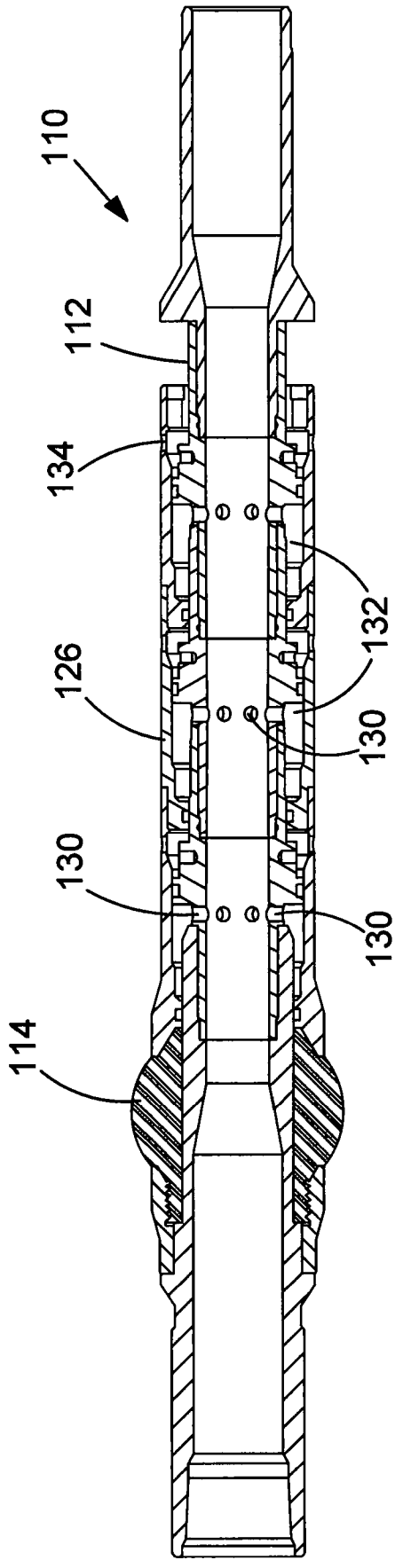


FIG.10b

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/051395

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B33/12 E21B43/10
ADD.

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)
E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	GB 2 401 131 A (WEATHERFORD LAMB [US]) 3 November 2004 (2004-11-03) pages 3, 16 - page 18; figures 6, 7, 10, 16	1-4,6-8, 13-16,18 9,11,16, 17,19
Y	GB 2 437 467 A (ENVENTURE GLOBAL TECHNOLOGY [US]) 24 October 2007 (2007-10-24) paragraphs [0005], [0083], [0084] - paragraphs [0146], [0147], [0221], [0273]; claim 17; figures 3, 4, 5	9,11,17, 19
X Y	WO 01/18353 A1 (E2 TECH LTD [GB]; INNES GARETH [GB]; OOSTERLING PETER [NL]) 15 March 2001 (2001-03-15) pages 1, 2 - page 18; figure 1	15 16

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"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
27 July 2017	03/08/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Patrascu, Bogdan

2

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 2005/045342 A1 (LUKE MIKE A [US] ET AL) 3 March 2005 (2005-03-03) the whole document	1-19
A	WO 03/056128 A1 (WEATHERFORD LAMB [US]; HARDING RICHARD PATRICK [GB]; LAURITZEN ERIC J) 10 July 2003 (2003-07-10) the whole document	1-19
A	WO 03/021080 A1 (WEATHERFORD LAMB [US]; LAURITZEN J ERIC [US]; SIMPSON NEIL ANDREW ABER) 13 March 2003 (2003-03-13) the whole document	1-19

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2017/051395

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