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(12) # EUROPEAN PATENT APPLICATION

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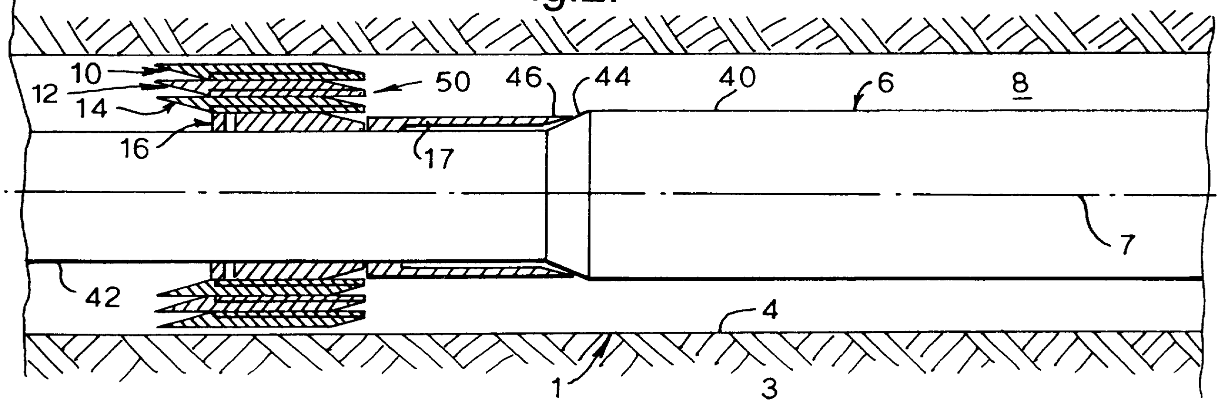
(54) **Method of sealing an annular space**

(57) A method is provided of sealing an annular space formed between an outer cylindrical member and an inner cylindrical member extending within the outer cylindrical member, the method comprising positioning a set of annular seal elements in the annular space in a manner that the seal elements are mutually displaced in axial direction of the cylindrical members, and axially moving the seal elements relative to each other in a manner that the seal elements become radially stacked so as to form a set of radially stacked seal elements.

Fig.2.



EP 1 277 915 A1

Description

[0001] The present invention relates to a method of sealing an annular space formed between an outer cylindrical member and an inner cylindrical member extending within the outer cylindrical member. In the industry of hydrocarbon fluid production from an earth formation it is conventional practice to seal an annular space in a wellbore formed in the earth formation. For example, the annular space can be defined between the wellbore wall being the outer cylindrical member and a tubular member being the inner cylindrical member, wherein the tubular member can be a hydrocarbon fluid production tubing or a wellbore casing. Alternatively the annular space can be formed between two tubular members extending into the wellbore, such as between a wellbore casing being the outer cylindrical member and a hydrocarbon fluid production tubing being the inner cylindrical member.

[0002] Such annular spaces have been sealed by application of expandable packers, plugs or by cementing the annular space.

[0003] However, a common problem for such applications is that it is generally difficult to create tight seals which can withstand high differential fluid pressures, especially in relatively large annular spaces, or to insert expandable packers or plugs into the wellbore in a manner that wellbore operations are not hampered thereby.

[0004] It is therefore an object of the invention to provide an improved method of sealing an annular space formed between an outer cylindrical member and an inner cylindrical member extending within the outer cylindrical member, which method overcomes the indicated problems.

[0005] Accordingly the method of the invention comprises the steps of:

a) positioning a set of annular seal elements in the annular space in a manner that the seal elements are mutually displaced in axial direction of the cylindrical members;
b) axially moving the seal elements relative to each other in a manner that the seal elements become radially stacked so as to form a set of radially stacked seal elements.

[0006] It is thereby achieved that installing of the seal elements in the annular space is relatively easy because the thickness of the individual seal elements is significantly smaller than the width of the annular space, so that the seal elements can be manoeuvred easily through the annular space. Alternatively, when the seal elements are arranged at one of the two cylindrical elements before insertion of the inner element into the outer member, the relatively small thickness of the seal elements compared to the width of the annular space allows adequate manoeuvring of the inner member into the outer member. Thereafter the seal elements are moved towards each other in axial direction so as become radially stacked and to form a tight seal in the annular space. The method of the invention can even be applied to seal relatively large annular spaces, for example by applying more seal elements and/or by applying thicker seal elements.

[0007] To achieve adequate tight sealing, suitably in step b) for each pair of adjacent seal elements a first seal element of the pair is induced to slide along a radially outer or inner surface of a second seal element of the pair.

[0008] For example, the first seal element of each pair of adjacent seal elements can be made of a flexible material, and wherein in step b) the first seal element is radially extended during sliding along said radially outer surface or radially compressed during sliding along said radially inner surface.

[0009] Suitably the first seal element of each pair of adjacent seal elements is induced to slide along said radially outer surface of the second seal element of the pair.

[0010] To promote initial sliding of adjacent seal elements along each other, it is preferred that the seal elements have tapered edges oriented such that the first seal element is induced to slide along the radially outer or inner surface of the second seal element of the pair upon relative axial movement of the first and second seal elements towards each other.

[0011] Suitably, in step a) a moving device and a stop device are arranged at axially opposite sides of the set of the seal elements, the stop device being fixedly connected to at least one of said cylindrical members, the moving device being axially movable relative to said cylindrical members, and wherein step b) includes axially moving the moving device in the direction of the stop device so as to axially move the seal elements towards each other.

[0012] For example, the moving device can be axially moved in the direction of the stop device by radially expanding a portion of the inner cylindrical and gradually increasing the length of the expanded portion in the direction of the stop device.

[0013] Such expansion process can be achieved by gradually moving an expander through the inner cylindrical member.

[0014] The invention will be described hereinafter in more detail and by way of example with reference to the accompanying drawings in which

Fig. 1 schematically shows a system for use in an embodiment of the method of the invention, during a first stage of use thereof;
Fig. 2 shows the system of Fig. 1 during a second stage of use thereof; and
Fig. 3 shows the system of Fig. 1 during a third stage of use thereof.

[0015] In the Figures like reference numerals relate to like components.

[0016] Referring to Fig. 1 there is shown a wellbore 1 formed into an earth formation 3 whereby the wellbore wall is indicted by reference numeral 4. A tubular member in the form of metal wellbore casing 6 with longitudinal axis 7extends substantially concentrically into the wellbore 1. Thus, in the context of the present invention the wellbore wall 4 and the casing 6 form respective outer and inner cylindrical members whereby an annular space 8 is formed between said cylindrical members. It is to be understood that the wellbore wall 4 does not need to be perfectly cylindrical, as the wall generally is of irregular shape due to, for example, washouts which occur during the drilling process. The casing 6 is provided with a set of three annular seal elements 10, 12, 14 arranged around the casing 6 and being mutually displaced in axial direction thereof, and with a stop device in the form of annular stopper 16 fixedly connected to the casing 6 and arranged at one side of the set of sealing elements. Furthermore, the casing is provided with a moving device in the form of metal compression sleeve 17 arranged at the other side of the set of seal elements 10, 12, 14. The compression sleeve 17 is movable relative to the casing 6 in axial direction thereof.

[0017] The seal elements 10, 12, 14 are made of a flexible material, e.g. rubber, and are strengthened in axial direction by axially extending reinforcement bars (not shown) embedded in the flexible material. Seal element 10 has a tapered edge 18 adjacent seal element 12, seal element 12 has a tapered edge 20 adjacent seal element 10 and a tapered edge 22 adjacent seal element 14, and seal element 14 has a tapered edge 24 adjacent seal element 12 and a tapered edge 26 adjacent stopper 16. The stopper 16 has a tapered edge 28 adjacent seal element 14. The tapered edges 18, 20 are oriented such that seal element 10 is induced to slide along radial outer surface 30 of seal element 12 when seal element 10 is pushed in the direction of seal element 12. Similarly, the tapered edges 22, 24 are oriented such that seal element 12 is induced to slide along radial outer surface 32 of seal element 14 when seal element 12 is pushed in the direction of seal element 14. Furthermore, the tapered edges 26, 28 are oriented such that seal element 14 is induced to slide along radial outer surface 34 of stopper 16 when seal element 14 is pushed in the direction of stopper 16.

[0018] The casing 6 has a radially expanded portion 40, a radially unexpanded portion 42, and a transition portion 44 located between the expanded and unexpanded portions 40, 42 and a having a diameter varying from the unexpanded diameter to the expanded diameter.

[0019] The stopper 16, the seal elements 10, 12, 14, and the compression sleeve 17 are all arranged around the unexpanded portion 42 of the casing whereby the compression sleeve 17 is arranged adjacent the transition portion 44 of the casing.

[0020] The compression sleeve 17 has an edge 46 adjacent the expanded portion 40 of the casing 6, which is provided with bearing means, e.g. a set of bearing balls regularly spaced along the circumference of the edge, a bronze bushing or a hydrostatic bearing, which ensures low friction between the edge and the transition portion 44 of the casing 6.

[0021] During normal operation the casing 6 is installed in the wellbore lwith the stopper 16, the seal elements 10, 12, 14, and the compression sleeve 17 present on the casing 6 as shown in Fig. 1. An expander (not shown) is then pushed or pulled through the casing 6 to radially expand the casing 6 and thereby to form the initial expanded portion 40 thereof. A suitable expander is, for example, a conical expander or a conical expander provided with rollers along the contact surface with the casing. By the expansion process the casing 6 is plastically deformed.

[0022] Subsequently the expander is moved through the casing 1 in the direction of stopper 16 thereby increasing the length of the expanded portion 40 and moving the transition portion 44 in the direction of stopper 16. Upon contact of the transition portion 44 with the edge 46 of the compression sleeve 17, continued movement of the transition portion 44 induces the compression sleeve to move in the direction of stopper 16. The compression sleeve 17 thereby induces seal element 10 to move against seal element 12 and subsequently to slide along the radial outer surface 30 thereof. When seal element 10 becomes fully arranged around seal element 12, continued movement of the transition portion 44 induces the compression sleeve 17 to move seal element 12 against seal element 14 and subsequently to slide along the radial outer surface 32 thereof. When seal elements 10, 12 become fully arranged around seal element 14, continued movement of the transition portion 44 induces the compression sleeve 17 to move seal element 14 against stopper 16 and subsequently to slide along the radial outer surface 34 thereof.

[0023] As shown in Fig. 2, a set 50 of radially stacked seal elements has thus been formed.

[0024] Referring further to Fig. 3, movement of the expander is continued so that movement of the transition portion 44 is continued. Since the stopper 16 prevents any further axial movement of the compression sleeve 17 and the set 50 of radially stacked seal elements, continued movement of the transition portion 44 leads to radial expansion of the compression sleeve 17, the stopper 16 and the set 50 of radially stacked seal elements. The set 50 of radially stacked seal elements thereby becomes firmly compressed between the stopper 16 and the borehole wall 4 so as to form an annular seal there between.

[0025] In this manner it is achieved that an annular seal is created between the casing 6 and the borehole wall 1, whereby a relatively large annular space is initially present there between and whereby the individual components of the seal are relatively thin so that installation of the casing 6 in the wellbore 1 is not hampered by the seal.

[0026] Instead of sealing an annular space between a casing and a wellbore wall, an annular space between two tubular elements can be sealed with the method of the invention. The two tubulars can be wellbore tubulars, and the inner tubular can extend only a short distance into the outer tubular. For example, the method of the invention can be applied to seal an annular space between two axially overlapping wellbore tubulars which are to be radially expanded to form an assembly of expanded wellbore tubulars of substantially equal inner and/or outer diameter.

[0027] Instead of strengthening the seal elements in axial direction by axially extending reinforcement bars (not shown) embedded in the flexible material, the seal elements can be made of or provided with an anisotropic material of higher axial stiffness than circumferential stiffness.

Claims

1. A method of sealing an annular space formed between an outer cylindrical member and an inner cylindrical member extending within the outer cylindrical member, the method comprising

a) positioning a set of annular seal elements in the annular space in a manner that the seal elements are mutually displaced in axial direction of the cylindrical members; and
b) axially moving the seal elements relative to each other in a manner that the seal elements become radially stacked so as to form a set of radially stacked seal elements.

2. The method of claim 1, wherein in step b) for each pair of adjacent seal elements a first seal element of the pair is induced to slide along a radially outer or inner surface of a second seal element of the pair.

3. The method of claim 2, wherein the first seal element of each pair of adjacent seal elements is made of a flexible material, and wherein in step b) the first seal element is radially extended during sliding along said radially outer surface or radially compressed during sliding along said radially inner surface.

4. The method of claim 2 or 3, wherein the first seal element of each pair of adjacent seal elements is induced to slide along said radially outer surface of the second seal element of the pair.

5. The method of any one of claims 2-4, wherein the seal elements have tapered edges oriented such that the first seal element is induced to slide along the radially outer or inner surface of the second seal element of the pair upon relative axial movement of the first and second seal elements towards each other.

6. The method of any one of claims 1-5, wherein in step a) a moving device and a stop device are arranged at axially opposite sides of the set of the seal elements, the stop device being fixedly connected to at least one of said cylindrical members, the moving device being axially movable relative to said cylindrical members, and wherein step b) includes axially moving the moving device in the direction of the stop device so as to axially move the seal elements towards each other.

7. The method of claim 6, wherein the moving device is axially moved in the direction of the stop device by radially expanding a portion of the inner cylindrical and gradually increasing the length of the expanded portion in the direction of the stop device.

8. The method of claim 7, wherein the length of said portion is increased by gradually moving an expander through the inner cylindrical member.

9. The method of claim 7 or 8, wherein the set of radially stacked seal elements is radially compressed between said inner and outer cylindrical members by radially expanding the inner cylindrical member at the location of the set of radially stacked seal elements.

10. The method of any one of claims 1-9, wherein said inner and outer cylindrical members are tubular members extending into a wellbore formed into an earth formation.

11. The method of any one of claims 1-9, wherein the inner cylindrical member is a tubular member extending into a wellbore formed into an earth formation, and the outer cylindrical member is the wellbore wall.

12. The method substantially as described hereinbefore with reference to the accompanying drawings.

Fig.1.

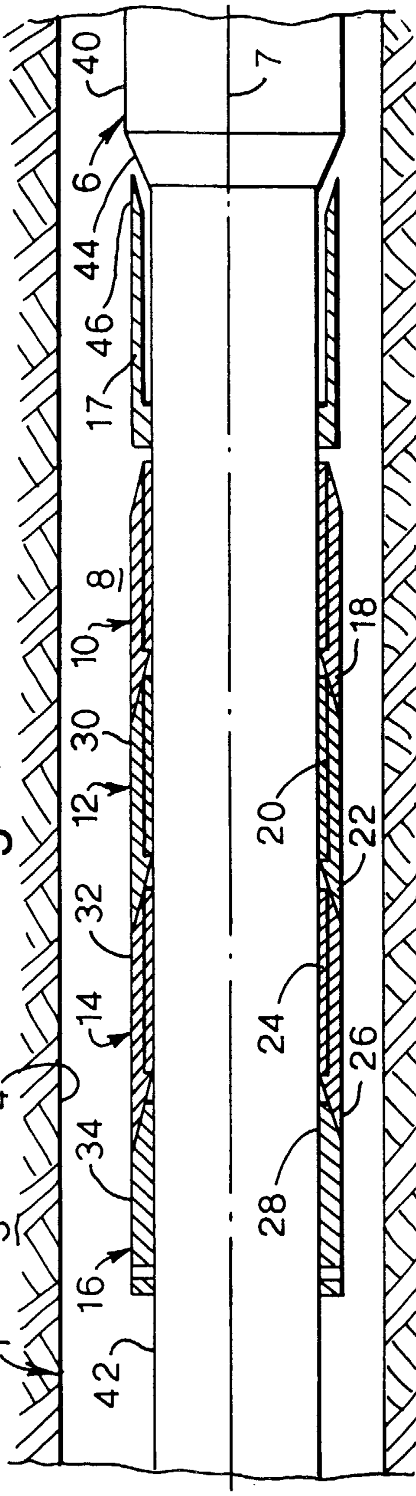

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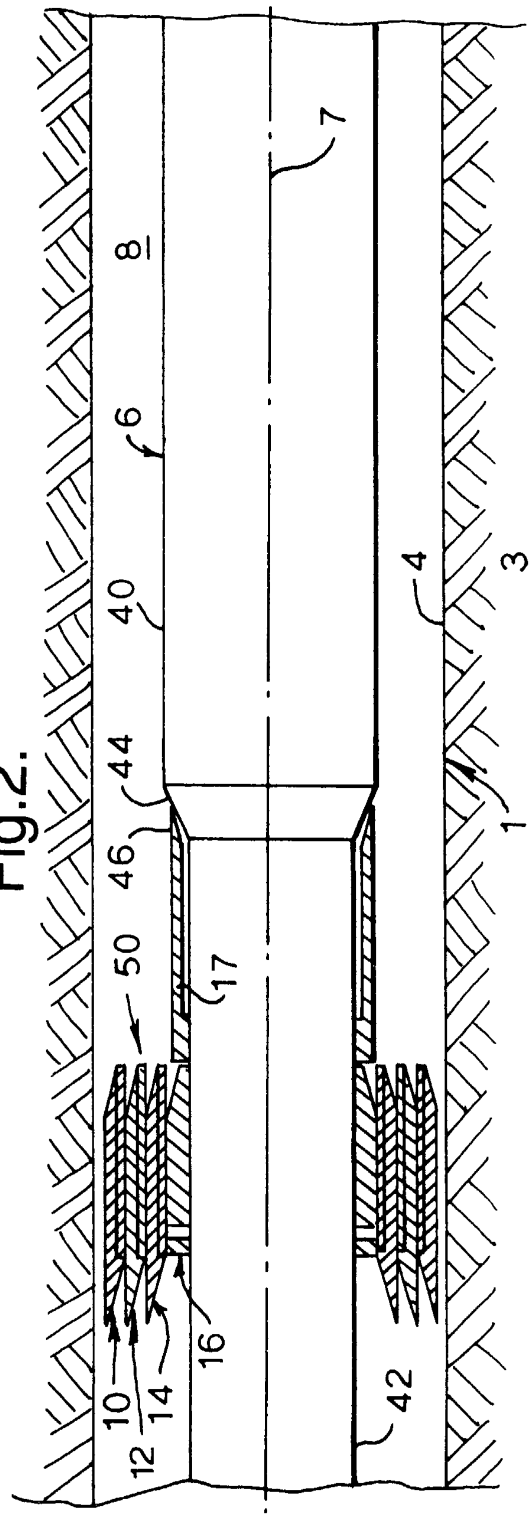
Fig.2.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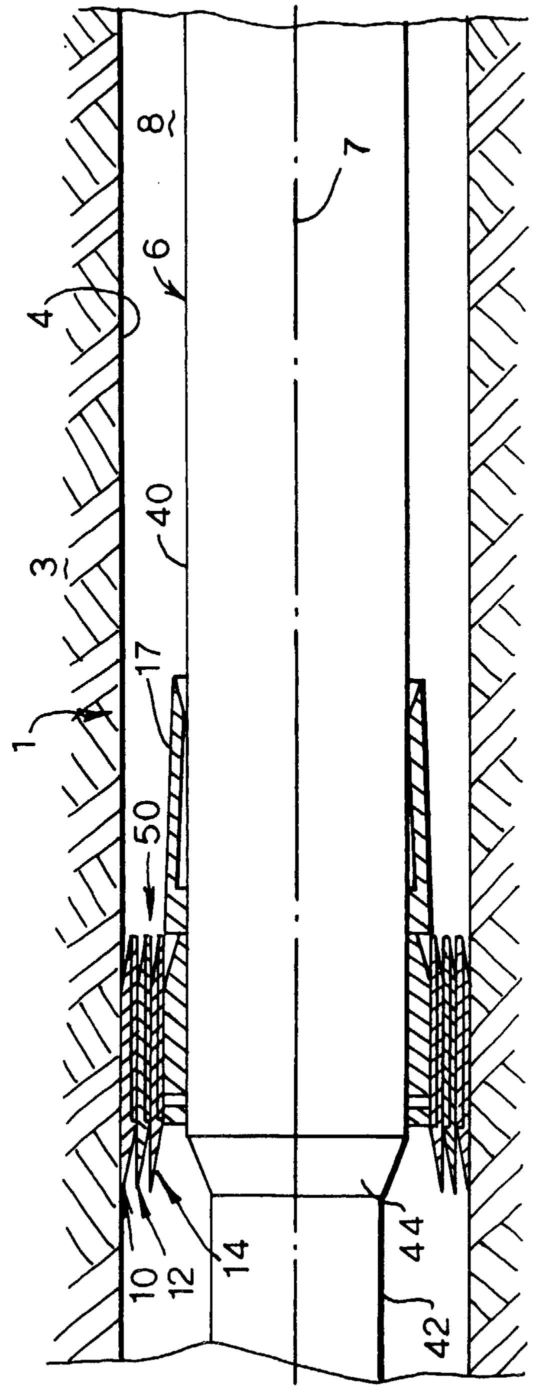

Fig.3.

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EUROPEAN SEARCH REPORT

Application Number
EP 01 30 6177

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 3 587 736 A (BROWN CICERO C) 28 June 1971 (1971-06-28) * figures 1,2 *	1-6,10, 11	E21B43/10 E21B33/128
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)
E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 November 2001	Schouten, A

CATEGORY OF CITED DOCUMENTS

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21-11-2001

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