

Plug, and methods for setting and releasing the plug

Introduction

The present invention relates to a plug and to methods for setting and releasing the plug in a well, for example, a hydrocarbon well, as disclosed in the independent apparatus claim and in the independent method claims.

Background/prior art

It is common practice to close off the borehole, either temporarily or permanently, by using plugs. The background for this may be that it is desirable, for example, to carry out tests or maintenance in the well. The plugs are usually run down the well using a running tool. When the plug has reached the desired depth in the well, it is secured to the surrounding casing or borehole wall using anchoring elements. The borehole is subsequently sealed, often by using packers which seal the area between the pipe or plug and the borehole wall. The bridge plug shown in US 6220348 B1, and the whole running tool, must be pulled out of the well if another operation is to be carried out in the well, which will mean a great deal of extra time and costs.

Known plugs for use in wells have the disadvantage that the plugs require maintenance between each operation.

It is usual to set and release plugs by means of rotation, but it can be difficult to achieve controlled rotation at great well depths. There are several potential sources of error which make the setting and release hazardous. One such source of error could be left-hand (anti-clockwise) rotation, which may result in equipment such as drill pipes or plugs being unscrewed from one another.

It is an object of the invention to resolve some of the drawbacks of the prior art. The object is achieved by means of a plug and methods for its setting and release according to the independent claims, with embodiments of the invention disclosed in the dependent claims. The setting and release take place essentially by means of axial movement of the pipe. By this is meant that an up-and-down movement applied to the plug is transmitted into a rotational movement that applies to the plug a moment which it wishes to release through a locking system. Another object is to provide a plug which can be used for several operations in a well with little call for maintenance of the plug between the different operations.

In the present invention, according to independent claim 1, a plug for a hydrocarbon well is defined, wherein the plug can be held in place relative to a casing/borehole, and wherein the plug further comprises a slip actuator for setting and releasing slips, a locking element in contact with the slip actuator, and one or more resilient packing elements which are adapted for sealing against the casing/borehole wall, and wherein the locking element comprises multiple parts having internal threads

which constitute an enclosure around threads on a pipe, and where on the radial outer surface of the locking element there are arranged resilient elements, and that

- the locking element, when setting the plug, is capable of sliding over the pipe threads for movement of the slip actuator and setting of the slips, and that the locking element comes into engagement with a locking sleeve to prevent rotation of the locking element,

- whilst when releasing the plug, the locking sleeve is released from the locking element, the locking element rotates off the pipe threads and the slips are released.

10 The invention also relates to a method for setting the plug in a well, wherein the setting is activated by an axial movement of the pipe, and where the movement further causes a guide sleeve to apply a force on the locking element which, by means of its high-pitch threads against the pipe, will slide over the threads and exert a force on the slip actuator which presses the slips out into firm engagement with the casing/borehole wall. By high-pitch threads here is meant threads that will rotate off a corresponding threaded part in only a few turns.

The invention relates also to a method for releasing the plug wherein an axial movement of the pipe activates the release of the locking sleeve from the locking element, such that the locking element is free to rotate off the threads on the pipe and the slips are released. Axial movement may be a movement up or down, or a combination thereof.

20 The setting or release of the plug should not take place unless desired. Up and down movement of the vessel, as a consequence of the rolling of the sea, may inadvertently start the setting. To avoid undesired setting and release, a first and a second hydraulic timer may be provided in connection with the plug for setting and release, respectively. The timers, one for setting and one for release, ensure that the setting or release does not start until the pressure from the surface acts over a given time period. The timers each consist of two hydraulic fluid chambers, where fluid from one of the chambers starts to flow over into the other chamber as a result of pressure that is applied to the pipe from the surface. If the pressure is not applied for a sufficiently long time, as, for example, on the heave of the waves, all the fluid will not flow between the chambers, and the setting or the release will not be started. Once all the fluid has flowed between the chambers, the setting or the release will start.

On the pipe there may be provided at least one fixed pin that is movable in a recess in a guide sleeve on the plug. The recess in the guide sleeve may be helical. This makes it possible for the operator to know at all times where the plug is in the setting or release process, in that the pin element follows the axial movements of

the pipe, up-down-up, as the pipe is pushed down into the well or pulled upwards. An axial movement of the pipe, and thus of the pin in the recess, will cause the axial movement to be transmitted into a rotational movement of the guide sleeve depending on the form of the recess.

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A holding member with radially acting elements can hold the plug essentially fixed to the casing/borehole wall during the setting. During the setting, but not necessarily during the release, the holding member will be in end contact with a guide sleeve, and a locking element will be in end contact with the second end of the guide sleeve.

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In an embodiment, the setting involves that a locking element with locking grooves, which during setting of the plug is so arranged as to allow the locking element on an axial movement of the pipe to slide over corresponding threads on the pipe, engages with corresponding locking pins on the locking sleeve and is prevented from being screwed off the threads. The locking sleeve is held fixed in the rotational direction, but is movable in an axial direction relative to the pipe. The configuration of the locking grooves on the locking element and the locking pins on the locking sleeve may be any configuration suitable to prevent rotation. On locking, and before the locking element is locked in the locking sleeve, the axial movement of the pipe will set slips, and the plug will be anchored to the casing/borehole wall. Resilient packing elements arranged on the plug seal against the casing/borehole wall when compressed. In connection with the compressible resilient packing elements, one or more backstop elements are provided which are fixed relative to the pipe. The backstop elements follow the movement of the pipe, and a further movement of the pipe, after the slips have been set, will cause the resilient packing elements to be compressed between the slips and the backstop elements.

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When releasing the plug, the pipe is by means of the running tool run down to the plug. A timer controls the activation of the release. After the activation of the timer, the pipe is moved a given length. This movement causes the slips to be released thereby releasing the anchoring against the casing/borehole wall, and the engagement between the locking grooves on the locking element and the locking pins on the locking sleeve is broken. On release of the slips, the holding force from the slips against the resilient packing elements is removed. The resilient packing elements will therefore no longer be kept compressed, but are free to expand in an axial direction. The axial force from the resilient packing elements will act on the locking element such that the locking element rotates off the threads on the pipe.

Description of the invention

One embodiment of the invention will now be described with reference to the attached drawings, wherein:

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Figure 1 shows a plug coupled to a running tool and a pipe at the start of setting;

Figure 2 shows the setting according to Figure 1 with the slips out;

Figure 3 shows the beginning of the release of the plug;

Figure 4 shows the release of the plug;

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Figure 5 shows a locking element on the outer surface of a pipe, and a locking sleeve;

Figure 6A shows a pin arranged on a pipe, where the pin is in a first position, movable in a recess on a guide sleeve;

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Figure 6B shows the pin in a second position, where the pipe is pulled towards the surface;

Figure 6C shows the position of the pin in the recess as the setting process starts and the pipe is pushed downwards;

Figure 6D shows the pin in its end position when the setting process has been completed;

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Figure 7 shows the timer function of the present invention.

Detailed description

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Reference is first made to Figures 1-4, which show a plug 1 coupled to a running tool 13 and a pipe 15. The lower end of the plug is shown to the right in the figure. The internal pipe of the plug 1, the running tool 13 and the pipe 15 are referred to below as pipe 15. At the lower end of the plug 1 there is arranged a holding member 10 with radially acting elements 12 for holding the plug fixed relative to the casing/borehole wall, see Figure 2. There is further shown a first 2 and a second 42 hydraulic timer which control the activation of the setting and the release of the plug 1. Furthermore, a pin 3 is arranged on the lower end of the pipe 15. A guide sleeve 4, which is a part of the plug 1, has a recess 16 in which the pin 3 can move. Arranged in end contact with the guide sleeve 4 is a rotatable locking element 5, consisting of multiple parts, having internal high-pitch threads 17 capable of engaging with corresponding high-pitch threads 18 on the radial outer surface of the pipe 15, best shown in Figure 5. Furthermore, on the radial outer surface of the locking element 5 there are resilient elements 6 which form an enclosure around the parts that constitute the locking element 5.

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The locking element 5 has arranged at one of its end portions locking grooves 11 capable of engaging with corresponding locking pins 19 in a locking sleeve 7. The locking sleeve 7 is fixed in the rotational direction but is movable in an axial direction, see Figure 5. The locking grooves 11 on the locking element 5 are formed

of radially inward facing pins. The corresponding locking pins 19 on the locking sleeve 7 consist of axially projecting pins, which are locked in the locking grooves 11 on the locking element 5. On the radial outer surface of the locking sleeve 7 is a slip actuator 8, which is capable of coming into contact with the locking element 5, see Figures 1 and 2. The slip actuator 8 has at least one conical end portion which is adapted for pushing slips 9 out into engagement with the casing/ borehole wall in order to secure the plug 1 in the well.

At the upper end of the plug 1, resilient packers 20 are provided which seal between the pipe 15 or plug 1 and the casing/borehole wall. In connection with the resilient packing elements 20, backstop elements 41 are arranged thereabove that are fixed relative to the pipe 15 and follow the movement of the pipe 15.

Setting

Figures 6A-6D show, step by step, the position of the pin 3 in the recess 16 during the process of setting the plug 1.

During the running down of the pipe 15, the pin 3 is in the position shown in Figure 6A. When the plug is at the desired depth in the well, the running down of the pipe 15 with the attached running tool 13 and the plug 1 is stopped, and the setting process starts. The pipe 15 is pulled back slightly, and the pin 3 follows the recess 16 to its next position in the guide sleeve 4 (Figure 6B), which causes the guide sleeve 15 to rotate as a result of the movement of the pin 3 in the recess 16.

Pressure is then applied from the surface over a predetermined period of time whilst the pipe 15 is run down. The pin 3 will then follow the pipe 15 and come into the position shown in Figure 6C, where the setting process starts. The pipe 15 is subsequently pushed on downwards until the pin 3 reaches the vertical end position in the recess 16 (Figure 6D).

The time interval for how long pressure is to be applied to the pipe 15 is determined in advance, and is given by how long it takes before all fluid in the hydraulic timer 2 has migrated from the first chamber to the second chamber, see Figure 7. Such a time period is, for example, set to at least 20 seconds so as to prevent the axial movement of the pipe 15 from being confused with natural heave motions of the vessel owing to the motion of the sea. The first 2 and the second 42 hydraulic timer may therefore be regarded as a dampener for the setting and release, respectively, as it filters out the natural heave motions of the platform, and only activates the setting and release of the plug when the pressure on the pipe 15 has acted for at least as long as the predetermined time period.

When all fluid has flowed over from one chamber to the other chamber in the first hydraulic timer 2, the setting of the plug 1 starts. A holding member 10 with radially acting elements 12 on the plug 1 essentially holds the plug 1 fixed to the casing/borehole wall, see Figures 1-4. The pipe 15 is moved down and the pin 3

follows the vertical groove in Figures 6C and 6D in the recess 16 on the guide sleeve 4, whilst the radially acting elements 12 on the holding member 10 hold the plug 1 fixed relative to the casing/borehole wall. The guide sleeve 4, wherein the pin 3 follows the recess 16, is in abutment with the holding member 10 secured to the casing/borehole wall, and will exert a force against the first end of the above-lying locking element 5, see Figure 2. The locking element 5, which consists of multiple parts with internal high-pitch threads 17, has resilient elements 6 on its outer surface which enable the locking element 5 to slide over the corresponding high-pitch threads 18 on the pipe 15, see Figure 5. The resilient elements 6 on the outer surface of the locking element 5 have as their only purpose to hold together the multiple parts which constitute the locking element 5, and do not represent any major force on the locking element 5 in the radial direction against the pipe 15. This means that the internal threads 17 of the locking element, during the setting of the plug 1, slide over the threads 18 of the pipe 15, without being screwed on. The locking element 5, at its other end, is in abutment with a slip actuator 8 which rests against the radial outer surface of the locking sleeve 7. An upwardly directed movement of the locking element 5 will exert an upward movement on one end of the slip actuator 8. The slip actuator 8 may be conical at its other end and an upward axial movement of the slip actuator 8 will press the slips 9 out into engagement with the casing/borehole wall, see Figure 2. At the same time, as can best be seen from Figure 5, when the internal threads 17 of the locking element 5 essentially completely cover the pipe threads 18, locking grooves 11 on the locking element 5 will engage with corresponding locking pins 19 on the locking sleeve 7 and ensure that the locking element 5 is held locked in the rotational direction. The locking sleeve 7 is secured to the pipe 15 in the rotational direction and rotational forces from the locking element 5 will be locked in the locking sleeve 7. The locking element 5 is now secured to the locking sleeve 7, the slips 9 are in contact with the casing/borehole wall, and the plug 1 is secured in the well. The pin 3 in the recess 16 is now in the vertical end position, as shown in Figure 6D. After the slips 9 have been set and the pin 3 has reached its vertical end position, pressure is again applied from the surface on the pipe 15 such that the resilient packing elements 20 are compressed between the secured slips 9 from below and the backstop elements 41 from above. In this way, the wellbore is sealed between the pipe 15 or the plug 1 and the casing/borehole wall by the resilient packing elements 20. The pipe 15 with the attached running tool 13 can be released from the plug 1, and the plug 1 can be left in the well.

Release

When the plug is to be released from the casing/borehole wall, the pipe 15 is run down into engagement with the plug by the associated running tool 13, see Figure 3. Pressure is then applied from the surface over a given period of time such that the

second hydraulic timer 42 activates the release. When the running tool 13 is fastened to the plug 1, and the second hydraulic timer 42 has activated the release, the pipe 15 is pulled up. The corresponding locking grooves 11 and the locking pins 19 between the locking element 5 and the locking sleeve 7 will be separated from each other. The locking element 5 will now no longer exert any upward force on the slip actuator 8. The slips 9 will therefore be released from the casing/borehole wall. When the slips 9 are no longer set, the resilient packing elements 20 will no longer be subjected to any force from below from the slips 9, but only from above by the backstop elements 41. The resilient packing elements 20 will therefore expand and act as a spring against the locking element 5 and press on the locking element 5 in an axial direction such that the locking element 5 rotates off the threads 18 on the pipe 15. The radially acting elements 12 on the holding element 10 will furthermore be released from the casing/borehole wall and the plug 1 is free to be removed from the well, see Figure 4.

The invention has now been explained with reference to one embodiment. A person of skill in the art will understand that changes and modifications may be made to the embodiment described which are within the scope of the invention as defined in the attached claims.

PATENT CLAIMS

1. A plug (1) for a hydrocarbon well, wherein the plug (1) can be held fixed relative to a casing/borehole wall, and wherein the plug (1) further comprises: a slip actuator (8) for setting and releasing slips (9), a locking element (5) in contact with the slip actuator (8), and one or more resilient packing elements (20) which are adapted for sealing against the casing/borehole wall, *characterized in that* the locking element (5) comprises multiple parts having internal threads (17) which constitute an enclosure around threads (18) on a pipe (15), and wherein on the radial outer surface of the locking element (5) there are arranged resilient elements (6), and that
- the locking element (5), when setting the plug (1), is capable of sliding over the pipe threads (18) for movement of the slip actuator (8) and setting of the slips (9), and that the locking element (5) comes into engagement with a locking sleeve (7) in order to prevent rotation of the locking element (5);
- whilst when releasing the plug (1), the locking sleeve (7) is released from the locking element (5), the locking element (5) rotates off the pipe threads (18) and the slips (9) are released.
2. A plug (1) according to claim 1, *characterized in that* the plug (1) is held fixed to the casing/borehole wall by a holding member (10) with radially acting elements (12).
3. A plug (1) according to one of claims 1-2, *characterized in that* the setting and the release of the plug (1) is controlled by axial movement of the pipe (15).
4. A plug (1) according to one of claims 1-3, *characterized in that* the holding member (10) is in end contact with a guide sleeve (4) and that the locking element (5) is in end contact with the other end of the guide sleeve (4).
5. A plug (1) according to one of claims 1-4, *characterized in that* a pin (3) is provided on the pipe (15) which follows the movement of the pipe (15), the pin (3) being movable in a recess (16) in the guide sleeve (4).
6. A plug (1) according to one of claims 1-5, *characterized in that* the locking element (5) and the locking sleeve (7) have corresponding locking grooves (11) and locking pins (19).
7. A plug (1) according to one of claims 1-6, *characterized in that* the activation of the setting of the plug (1) is controlled by a first timer (2) that is activated by a specific pressure on the pipe (15) over a given period of time.
8. A plug (1) according to claim 7, *characterized in that* the at least one timer (2) is hydraulic, and that the pressure acting on the timer (2) controls the transfer of hydraulic fluid from a first chamber to a second chamber in the timer (2), and where

the setting starts when all hydraulic fluid has been transferred between the chambers.

5 9. A plug (1) according to one of claims 1-6, *characterized in* that the activation of the release of the plug (1) is controlled by a second timer (42) which is activated by a specific pressure on the pipe (15) over a given period of time.

10 10. A plug (1) according to claim 7, *characterized in* that the at least one timer (42) is hydraulic, and that the pressure that acts on the timer (42) controls the transfer of hydraulic fluid from a first chamber to a second chamber in the timer (42), and where the release starts when all hydraulic fluid has been transferred between the chambers.

11. A plug (1) according to one of claims 1-10, wherein the resilient packing elements (20) are compressed by setting of the slips (9), and on the release the resilient packing elements (20) expand axially, this axial expansion motion rotating the locking element (5) off the pipe threads (18).

15 12. A method for setting the plug (1) according to one of claims 1-11, wherein the setting is activated by an axial movement of the pipe (15), *characterized in* that the movement further causes a guide sleeve (4) to apply a force on the locking element (5) which, by virtue of its high-pitch threads (17) against the pipe (15), will slide over the threads (18) and exert a force on the slip actuator (8) which presses
20 the slips (8) out into firm engagement with the casing/borehole wall.

13. A method for release of the plug (1) according to claims 1-11, *characterized in* that an axial movement of the pipe (15) activates the release of the locking sleeve (7) from the locking element (5), such that the locking element (5) is free to rotate off the threads (18) on the pipe (15) and the slips (9) are released.

25 14. A method according to claim 13, *characterized in* that the locking element (5) rotates off the threads (18) on the pipe (15) in that resilient packing elements (20) on the plug (1) expand axially and act on the locking element (5).