[54] METHOD OF CEMENTING A CASING STRING IN A WELL BORE AND HANGING IT IN A SUBSEA WELLHEAD

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[57] ABSTRACT

Method of cementing a casing string in a well bore and hanging it in a subsea wellhead, a safety joint being incorporated in the string below a casing hanger secured to the latter, enabling the joint to be disconnected, in the event the casing string sticks in the well bore during its reciprocation while being cemented, and the casing string above the joint and the casing hanger removed. An extension tool secured to the lower end of a length of casing string is attached to the casing hanger and spaced therefrom a distance corresponding to the distance between the wellhead and upper end of the casing string cemented in the well bore, and is lowered to place the tool over such upper end, with the hanger landed in the wellhead, after which the casing string cemented in placed is pulled upwardly into and secured to the extension tool by slips of the tool.

5 Claims, 9 Drawing Figures
METHOD OF CEMENTING A CASING STRING IN A WELL BORE AND HANGING IT IN A SUBSEA WELLHEAD

The present invention relates to well bore methods, and more particularly to a method of securing a casing string in a subsea well bore and of landing the casing hanger in a subsea wellhead.

In drilling well bores on land, it is desirable to reciprocate the casing during the cementing operation to secure a better cement bond to the casing and prevent channeling of the cement in the annulus surrounding the well casing. After all of the cement has been pumped into place, the casing is held stationary while the cement sets up. Thereafter, a slip-type casing hanger is placed around the casing string to support the casing and seal against it. The slip-type casing hanger makes it possible to support and seal the casing at any point along its upper portion, regardless of the fact that the casing might back at any time during its reciprocation.

On wells drilled from floating drilling vessels, which use subsea wellheads on or near the ocean bottom, reciprocation has not been used heretofore because of the casing string sticking problem, and the fact that subsea casing hangers are secured to the casing string at its upper end and lowered with the casing toward a landing shoulder in a wellhead housing. If the casing string sticks during its reciprocation, the casing hanger will be located above the wellhead landing shoulder and cannot be lowered into engagement therewith. If the subsea casing hanger does not land on the wellhead shoulder or seat, then stack-up and space-out problems occur. In addition, the casing string might be put into compression, involving a very dangerous situation. If the casing string sticks during the running in of the casing hanger, with the casing hanger above its associated seat in the wellhead, expensive and time consuming operations are required to effect correction. Thus, the casing must be cut off accurately in the area just above the wellhead housing. The cutoff casing hanger, running tool and running string are recovered from the well. A “dressing mill” is run into the well to prepare the top of the cutoff casing so that a special emergency slip-type casing hanger can be run into the wellhead housing and landed in place. A casing spear is lowered inside the cutoff casing string to place it in tension in the slip assembly of the special emergency slip-type casing hanger. The casing spear and its running string are removed, after which the seal of the special emergency slip-type casing hanger is actuated, followed by recovery of the running string. The stub of casing sticking above the special emergency slip-type casing hanger is then cut off accurately and such stub of casing, the cutting tool and its running string removed.

With the present invention, a method is provided that allows the overall length of the casing string to be appropriately shortened in the event of the casing sticking in the well bore, with the casing hanger located above its normal seating position in the wellhead. This objective is accomplished by enabling the casing string to be disconnected at a convenient distance below the casing hanger and removed. This permits the casing hanger to be secured to a shorter length of casing string and lowered in the well bore and appropriately related to the main portion of the casing string remaining in the well bore, with assurance that the casing hanger is landed in the subsea wellhead. The casing string is then pulled upwardly into sealed and supporting relation to the lower part of the casing string thereafter.

As a result of the foregoing method, substantial savings in cost and time are effected. Assurance is also had that the casing string will be in tension, rather than in compression, within the well bore.

In general, an object of the invention is to provide a method of readily shortening the overall length of the casing string, to secure proper hanging of the casing hanger in the wellhead, and to eliminate the problems previously associated with the sticking of the casing during its reciprocation.

This invention possesses many other advantages and has other objects which may be made more clearly apparent from a consideration of a method embodying the invention. This method is shown and described in the present specification in connection with the drawings accompanying and constituting a part thereof. Such drawings and method will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense.

REFERRING TO THE DRAWINGS

FIG. 1 is a diagrammatic view of a subsea well bore, with a casing string therein, and within a marine riser extending from a wellhead housing to a floating drilling vessel at the top of the ocean, or other body of water;

FIG. 2 is a diagrammatic view of a casing string being reciprocated during its cementing process.

FIG. 3 is a diagrammatic view illustrating the lower main portion of a cemented casing string stuck in the well bore, with the casing hanger above the wellhead, and with a string shot being run for releasing a safety joint in the casing string; FIG. 4 is a view of the equipment disclosed in FIG. 3, with the casing hanger and the casing string above the safety joint removed;

FIG. 5 is a view illustrating an extension tool at the lower end of an emergency casing string telescoped over the upper end of the stuck casing, with the casing hanger landed in its seat in the wellhead;

FIG. 6 is a view similar to FIG. 5, illustrating the upper portion of the stuck casing string being pulled upwardly within the extension tool;

FIG. 7 is a view of the completed operation, with the casing spear and the associated running string removed, and with the hanger disposed on its seat in the wellhead to bold the casing string in tension;

FIG. 8 is an enlarged longitudinal section, a portion being disclosed in side elevation, of the safety joint portion of the original casing string;

FIG. 9 is a longitudinal section, with a portion shown in side elevation, of the extension tool telescoped over the upper end of a lower casing string to support the latter and to be sealed off with respect thereto, the extension tool being in the condition illustrated in FIG. 7.

As illustrated in the drawings, a well bore 10 has been drilled into a formation 11 underlying a body of water 12, such as an ocean, through use of a vessel 13 floating above the well bore, a suitable subsea wellhead 14 being disposed at the ocean floor and supporting an outer casing string 15 previously installed in the well bore and cemented in place. A suitable marine riser 16 extends between the subsea wellhead 14 and the floating vessel 13, and through which various operations in drilling the well bore, cementing casing therein, and performing other operations, occur.

As disclosed in the diagrammatic views in FIGS. 2 to 7, inclusive, the well bore 10 has been drilled below the lower end of the outer casing string 15. It is desired to run an inner casing string 17 into such well bore to a predetermined depth, cement such casing string in place, and support the casing string 17 by means of a casing hanger 18 secured to its lower end and landed on a seat 19 in the subsea wellhead 14, and which may be latched in place by a suitable hanger lock ring 20. The ring 20 may be a split inherently contractible lock ring mounted in an internal circumferential groove 21 in the wellhead and having a downwardly tapering surface 22 for engagement by the casing hanger 18 to be expanded outwardly within its groove 21 until the hanger lands on the lands seat 19, whereupon the lock ring will contract inherently over an upwardly facing casing hanger shoulder 23, to retain the hanger in the wellhead 14, in a known manner.

The string of casing 17 to be disposed within the well bore has its upper end suitably secured to the casing hanger 18, which, in turn, is releasably attached to a running tool 24 secured to a running string 25 that extends through the riser 16 to the drilling vessel 13. Normally, the casing string is lowered through the marine riser and into the well bore 10.
The casing hanger 18 is connected to the uppermost casing joint and to the running tool 24 attached to the running string 25, lowering of the casing string being continued until the casing hanger is adjacent to the wellhead 14. Circulation is then established down through the running string 25 and the casing string 17 to condition the well bore, after which the required charge of cement slurry is pumped down through the running string and the casing string to discharge from the lower end, or other predetermined point, of the latter, and for upward passage around the casing string to a desired elevation in the well bore. During the pumping of fluid and cement slurry through the casing string and out of the casing string 17, the latter is connected to prevent channelling of the cement in the annulus 26 surrounding the casing string, and to secure a better bond between the casing string and the wall of the surrounding well bore. After the desired amount of cement slurry has been pumped out of the casing string, the hanger 18 is lowered into engagement with its seat 19, the cement setting up and hardening around the casing string.

At times, the casing string 17 may stick in the well bore, leaving the casing hanger 18 disposed above the subsea wellhead 14, which introduces the difficult situation hereinafter described.

To enable the casing hanger 18 to be landed on its seat 19, and the casing string 17 placed in tension in the event it becomes stuck in the well bore, a safety joint 30 is incorporated in the casing string at a predetermined distance below the wellhead 14. In the event of the casing string sticking in the well bore, the running string 25, casing hanger 18 and upper portion 17a of the casing string can be released at the safety joint from the lower portion 17b of the casing string and withdrawn through the marine riser 16 to the drilling vessel 13.

The safety joint includes an elongate inner tubular member 31, the lower end of which is threadedly secured to an adjacent casing section 17b, such inner tubular member having a left-hand threaded pin 32 on its upper portion above which the tubular member has a smooth, external cylindrical surface 33 extending to a smooth tapered surface 34 at the upper terminal portion of the inner member. The safety joint further includes an elongate outer member 35 having a lower box 36 provided with a left-hand thread 37 mating with the pin thread 32 and having an internal smooth cylindrical surface 38, the upper end of which terminates at an upwardly tapering inner surface 39 companion to the upper tapered surface 34 of the inner member. When the threaded portions 32, 37 of the joint are further extended, the tapered surfaces 34, 39 contact each other to provide a metallic seal between the inner and outer members. As further assurance against leakage between the inner and outer tubular members, an elastomer side seal 40 may be provided in a groove 41 in the outer member, engaging the tapered surface 34 of the inner member. The inner and outer members are of any suitable length, being, for example, about 10 to 12 feet in length from the upper ends of their threads 32, 37 to their tapered seal portions 34, 39.

The safety joint 30 is incorporated in the casing string, as described above. If reciprocation of the casing string 17 does not result in its sticking, the casing hanger 18 is landed and locked in place in the subsea wellhead 14, after which the running tool 24 can be released from the casing hanger 18 and elevated on the running string 25 to the drilling vessel. If, however, the casing string sticks so that the hanger 18 does not reach its companion seat 19 in the wellhead, it is necessary to shorten the overall length of the casing string 17. A string shot (FIG. 3) is lowered on a suitable wireline 45 through the running string 25 into the casing, and is set off within the threads portion 32, 37 of the safety joint 30, while right-hand torque is applied by the running string to rotate the upper portion 17a of the casing string and the outer member 35 relative to the inner member 31, to unthread the outer member from the inner member and allow the outer portion 35 of the safety joint, together with the casing portion 17a, casing hanger 18, running tool 24 and running string 25, to be recovered through the marine riser 16 to the drilling vessel, the main lower portion 17b of the casing string remaining cemented in the well bore, as illustrated diagrammatically in FIG. 4.

The outer portion 35 of the casing safety joint is removed from the lower end of the upper portion 17a of the casing string, and an expansion tool 50 (FIG. 9) threaded on the bottom of the latter, an appropriate length of casing 17c being provided between the extension tool 50 and the casing hanger 18 to correspond to the distance between the upper end of the casing 17b cemented in the well bore and the seat 19 in the wellhead 14, such that the lowering of the substitute casing string or casing string extension 17c will effect landing of the casing hanger on the wellhead seat and telescoping of the extension tool 50 partially over the inner tubular member 31 of the safety joint.

The extension tool 50 is secured to the lower end of the casing string extension 17c, the upper end of which is attached to the casing hanger 18, which, in turn, is secured to a running tool 24 attached to the running string 25, and lowered through the marine riser 16. The extension tool is telescoped over the upper portion of the inner tubular member 31 of the safety joint portion, whereupon the casing hanger 18 engages its companion wellhead seat 19. The extension tool (FIG. 9) includes an outer body 51 having an elongate internal circumferential groove 52 therein, in which a split slip ring 53 is disposed having inner upwardly facing teeth 54 adapted to grip the cylindrical surface 33 of the inner tubular member 31.

The slip ring also has a downwardly tapering external expansion surface 55 engaging a companion internal tapered surface 56 in an expander 57 emplaced by the inner wall or base 58 of the body groove 52. The lower end of the expander bears against the upper end of a stack of metallic frusto-conical seal rings 59 inclined in an upward and inward direction, the lower one of which bears against a back-up ring 60 resting upon a body shoulder 61 defining the lower end of the elongate groove 52.

When the casing hanger 18 is landed on its seat 19, the outer body 51 is telescoped over the upper cylindrical portion 31 of the inner tubular member 30, as disclosed diagrammatically in FIG. 5. A casing spear 70 of a known type is then secured to a tubing tension string 71 and lowered down through the running string 25 until the spear is located within the inner tubular member 31. An upward pull is now taken on the tension string 71, such pull pulling up the inner tubular member 31 and exerting an upward pull on the lower casing string 17b, stretching the latter and moving the elongate inner tubular member 31 upwardly within the outer body 51 of the extension tool 50, and to a position in which the upper end of the safety joint member is disposed above the slip ring 53 (FIG. 6). Relaxation of the tension on the tubing string 71 and casing spear 70 will cause the lower casing string 17b to tend to contract. However, the cylindrical surface 33 of the inner member 31 will be gripped by the teeth 54 of the slip ring, tending to shift the latter downwardly within the expander 57, the engaging tapered surfaces 55, 56 forcing the teeth more firmly into the periphery of the inner tubular member. The downward force, resulting from the tension in the lower casing string, will be transmitted from the expander 57 to the inclined metal seal rings 59, expanding the latter in inward and outward directions against the cylindrical periphery 33 of the inner tubular member 31 and the cylindrical base 58 of the groove, thus effectively sealing the outer body 51 with respect to the inner tubular member 31.

The casing spear 70 is now removed (FIG. 7), the lower casing section 17b continuously exerting a pull upon the casing string extension 17c through the slip 53, expander 57, seal rings 59 and outer body 51, this pull being transferred through the casing hanger 18 to the shoulder or seat 19 within the wellhead 14. The effective length of the casing string 17 has been restored, with the hanger 18 appropriately landed in the wellhead 14, and with the casing string 17 held in tension.
The casing hanger 18 can now be pressure tested in a known manner. If appropriately sealed in the wellhead 14, the running tool 24 is released and removed with the running string 25 through the marine riser 16 to the drilling vessel 13. Subsequent operations can now be performed in the usual manner.

I claim:

1. A method of hanging a well bore casing string from a wellhead, comprising providing a releasable threaded connection in the casing string at a predetermined location, said threaded connection comprising a lower inner tubular member forming the upper part of a lower portion of the casing string and threadedly connected to an upper outer tubular member forming the lower part of an upper portion of the casing string, lowering the casing string in the well bore, releasing the connection by rotating the upper portion of the casing string relative to the lower portion to unthread the upper outer tubular member from the lower inner tubular member, elevating the upper portion of the casing string from the well bore with the lower portion of the casing string remaining in the well bore, lowering a casing string extension in the well bore with an extension tool secured to its lower end and a casing hanger secured to its upper end, such casing string extension being of a predetermined length and being lowered until said extension tool telescopically over the periphery of said lower inner tubular member of said lower portion of the casing string and said hanger lands in the wellhead, and pulling the upper part of said lower casing string portion upwardly to shift said inner tubular member upwardly within said extension tool, said tool embodying gripping means which engages the periphery of said inner tubular member to prevent its movement downwardly of the extension tool, whereby said casing string extension and lower portion of the casing string are maintained in tension with the hanger landed in the wellhead.

2. A method as defined in claim 1; cementing the casing string in the well bore prior to release of the connection, and reciprocating the casing string in the well bore during the cementing operation.

3. A method as defined in claim 1; said threaded connection between said inner and outer tubular members being left hand.

4. A method as defined in claim 1; said casing string extension being lowered in the well bore on a first tubular running string releasably secured to the casing hanger, upward pulling of the upper part of said lower casing string portion being effected by lowering a spear through the running string and the casing string extension on a second running string, securing said spear to said upper part, pulling upwardly on the second running string, releasing the spear and removing the spear and second running string through the casing string extension and first running string, and then releasing said first running string from the casing hanger.

5. A method as defined in claim 4; firing a string shot lowered into the releasable connection to facilitate release of the connection upon rotation of the casing string above the connection, cementing the casing string in the well bore prior to release of the connection, and reciprocating the casing string in the well bore during the cementing operation.

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