HYDRAULICALLY SET CASING HANGER APPARATUS AND PACKING SLEEVE

ABSTRACT: Casing hanger apparatus for hanging a well casing in a casing head beneath a body of water, in which the hanger body is locked into the casing head by the application of fluid pressure, the seal between the casing head and the hanger body also being set by fluid pressure. Such a casing hanger in which the seal includes a longitudinally undulated metal ring deformable by axial force to expand inwardly and outwardly into sealing engagement with inner and outer cylindrical walls.
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In the drilling of oil and gas wells at an underwater site, different casing strings are hung to protect strata that have been drilled through from the pressures that may be required or encountered at greater depths. In many cases, a special housing is provided at or near the ocean bottom to support and seal off the casing string cemented in the well bore. With the special housing below water and a drilling rig above water, problems are encountered in supporting the casing string, circulating fluid for conditioning the well, cementing the casing string in the well bore, energizing a seal between the casing hanger and a previously set hanger or head, and, after testing the seal, removing the running tool and pipe on which the running tool is operated.

Particularly, in the case of drilling in deep water, where the pipe on which the running tool is operated must extend a substantial distance from the platform or floating vessel to the ocean floor, the application of high torque for setting conventional seals between the casing hanger and the subsurface housing or previously set casing hanger is objectionable.

Moreover, if the casing hanger is anchored in the housing or previously set casing hanger by a lock ring which is automatically engaged when the casing hanger lands in the housing or previously set hanger, the lock ring must be released in order to pull the casing hanger in the event that such pulling is necessary or desirable, say, before the cementing operation.

Accordingly, the present invention provides underwater casing hanger apparatus which is set by hydraulic pressure in locked or anchored engagement with the subsurface housing or previously set casing hanger.

The invention also provides underwater casing hanger apparatus in which the seal between the hanger body and the housing or previously set casing hanger is set by hydraulic pressure.

More particularly, the present casing hanger apparatus provides fluid pressure responsive piston and cylinder means for shifting anchoring means and sealing means to anchoring and sealing positions, when the casing hanger is to be anchored and sealed off, following the cementing of the casing string in the well bore, without requiring rotation of the running-in string of pipe on which the casing hanger is lowered through the water to the ocean floor and landed in the subsurface housing or previously set casing hanger.

In accomplishing the foregoing, the apparatus includes a packer or seal in the form of a sleeve or ring adapted to be engaged in sealing engagement with opposing cylindrical walls by the application of an axial force, the packer or seal comprising a longitudinally undulated deformable metal body which is deformed beyond its elastic limit when in engagement with the cylindrical walls. In the specifically illustrated embodiment, the packer or seal may also include elastomeric material which is also deformed upon the application of a force to deform the metal body, the elastomeric material engaging the opposing cylindrical walls to insure the prevention of leakage past the metal body.

An object of the invention is to provide a rugged and effective casing hanger apparatus capable of being anchored in an underwater housing or previously set casing hanger and sealed off by fluid pressure.

Another object is to provide a packing or seal device in which a metal body is deformed inwardly and outwardly into effective sealing relation to opposing cylindrical walls.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several forms in which it may be embodied. Such forms are shown in the drawings accompanying and forming part of the present specification. These forms 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, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIG. 1 is a view partly in elevation, with parts broken away, and showing a casing hanger and associated apparatus installed in and in association with a well bore underlying a body of water.

FIGS. 2a and 2b together constitute a quarter longitudinal section through casing hanger apparatus embodying the invention and landed in a surrounding hanger body or housing, the parts being illustrated in the initial condition which they occupy in lowering the apparatus from a drilling rig, FIG. 2b being a downward continuation of FIG. 2a;

FIGS. 3a and 3b together constitute a quarter longitudinal section, generally similar to FIGS. 2a and 2b, but showing the hanger body anchored in the housing or previously set hanger, and the seal or packer deformed and sealing off the space between the hanger and the housing or previously set casing hanger;

FIG. 4 is a transverse section taken on the line 4-4 of FIG. 2b.

FIG. 5 is a fragmentary longitudinal section illustrating the packed-off seal of the invention; and

FIG. 6 is a fragmentary longitudinal section illustrating a modified packed-off seal.

A typical installation of apparatus embodying the invention is illustrated somewhat diagrammatically in FIG. 1 in connection with a well bore A underlying an ocean or other body of water and extending downwardly from the ocean floor F. A suitable base structure B is supported on the ocean floor and carries an outer casing C of relatively large diameter suspended from a casing hanger D resting upon an outer housing seat E on the base and locked thereto by a suitable lock ring G. Disposed within the outer casing is an intermediate string of casing H extending downwardly into the well bore and suspended from a suitable casing hanger body J resting upon a companion tapered seat K in the outer body. One or a stack of blowout preventers N are connected by means of a suitable connector P to the head D, such as by a hydraulic connector illustrated in the U.S. Pat. No. 3,321,217, for "Coupling Apparatus for Well Heads and the Like," the blowout preventers, in turn, being connected by a suitable hydraulic or other connector R to a flexible joint S, made of sections, secured to a marine conductor pipe T extending to the drilling rig, which may be located on a drilling platform or on a floating vessel or structure (not shown). Another string of casing Y is disclosed in FIG. 1 as having been supported in a hanger W locked in packed-off condition in the intermediate hanger body J.

Referring now to FIGS. 2a and 2b, the casing hanger apparatus W includes a body 10 of annular form having a lower hanger thread 11 connected to the downwardly extending casing Y. The casing hanger body 10 has a downwardly facing tapered shoulder 12 adapted to engage an upwardly facing seat 13 in the previously set hanger body J, for example. At its upper end, the hanger body 10 has an internal left-hand threaded section 14 adapted for threading engagement by an externally threaded flange 15 on a mandrel 16 of a running tool, generally denoted at Z. At its upper end, the mandrel 16 has an internally threaded box 17 adapted to receive the externally threaded pin end 18 of a running-in string of pipe 19 extending to the drilling rig. Extending longitudinally through the mandrel 16 is a central passage 20 adapted to communicate with the pipe string 19 and the casing Y.

Accordingly, it is apparent that the string of casing Y may be lowered through the body of water and landed in a housing or previously set casing hanger, the downwardly facing shoulder 12 of the hanger body 10 supporting the casing string Y. Thereafter, cement may be displaced downwardly through the pipe string 19 and the mandrel passage 20, and thence downwardly through the casing string Y to the bottom thereof, then upwardly through the annular space 21 between the casing Y and the hanger body J, such fluent cement then passing through longitudinal passages 22 provided in the hanger body 10 and into the space above this hanger body, as is typical in the hanging of casing strings from subsurface housings and previously set liner hangers and the cementing of casings, as herein illustrated.
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However, it is desired that the hanger body 10 be anchored in the body J and that the running tool Z be disconnected from the hanger body 10, as well as that the space between the hanger body 10 and the body J be sealed off. Accordingly, the present invention provides anchor means, generally denoted at 23, for anchoring the hanger body 10 within the body J; actuator means, generally denoted at 24, for effecting operation of the anchoring means 23; and seal means, generally denoted at 25, for effecting a seal between the hanger body 10 and the body J. Also, the present invention provides a loading or cylinder sleeve 26, which may be reciprocally disposed about the piston 27 and the piston 26, suitable side seal rings 29 and 30 being provided, respectively, between the piston 27 and the piston 26 and internal, axially spaced cylindrical walls 31 and 32 of the loading sleeve 28. Internally of and integral with the loading sleeve 28 is an internal annular cylinder head 33 having a sealing ring 34 adapted for sealing engagement with external cylindrical wall 35 of the tool mandrel 16. This annular head 33 is disposed between the lower piston 26 and the upper piston 27 on the mandrel 16 and divides the annular space 36 between the mandrel and the loading sleeve 28 into a lower annular pressure chamber 37 below the cylinder head 33 and an upper pressure chamber 38 above the cylinder head 33.

The tool mandrel 16 is provided with lower annular ports 39 leading from the passage 26 through the mandrel into the lower chamber 37, the mandrel also being provided with upper ports 40 leading from the mandrel passage 20 into the upper chamber 38.

Mandrels are provided for normally closing the lower ports 39 and the upper ports 40 to prevent fluid communication between the mandrel passage 28 and either of the chambers 37 or 38. In the illustrative embodiment, this means comprises a sleeve 41 disposed in the mandrel passage 20 and seating on a lower mandrel shoulder 42 provided within the mandrel passage 28. The sleeve 41 spans both the lower and upper ports 39 and 40, and is provided with suitable side seal rings 43 and 44 spaced above and below the ports 40 and another side seal ring 45 spaced below the lower ports 39. At its upper end, the sleeve 41 has an internal channel or groove 46 providing an inwardly projecting flange 47 adapted to be engaged by a suitable tool (not shown) for engaging the flange 47 when the sleeve 41 axially upwardly so as to uncover the ports 39 and 40 during use of the apparatus, as will be hereinafter described, the sleeve 41 being elevated through the pipe 19 to the driller.

At its lower end, the loading sleeve 28 supports the seal means 55. More particularly, the seal means 25 includes a support collar or ring 50, which is detachably secured at its upper end to a reduced diameter end portion 51 on the lower end of the loading sleeve 28, as by means of a suitable number of circumferentially spaced seal pins 52. At its upper end 53, the thrust ring 50 is spaced downwardly from a downwardly facing shoulder 54 on the loading sleeve 28, so as to allow downward movement of the loading sleeve 28 relative to the support ring 50 when it is desired that the pins 52 be sheared during use of the apparatus.

Below the support ring 50, the seal means 25 includes deformable seal means 55, including a longitudinally unduluated coated metallic sealing ring section 56, which is integral in the illustrative embodiment with the support sleeve 50, and has at least one inner annular crest 56a and at least one outer annular crest 56b. Molded about the unduluated sleeve section 56 is an annular body of rubber or rubberlike, elastomeric material 57, the sleeve section 56 having lateral holes 58 through which the rubber body extends to assist in uniting the rubber with the sleeve section 56.

At its lower end, the unduluated sleeve section 56 has the locking means 23 thereon, including a series of downwardly extended circumferentially spaced deformable lock fingers 59. As seen in FIG. 4, these fingers 59 are of such extent circumferentially as to be readily flexed outwardly and are in such number as to positively anchor the casing hanger body 10 against the hanger body seat 13 and to the hanger body J, as well as to anchor the sealing means 25 against displacement after actuation of the seal means and the anchor means, as will hereinafter be described, whereby to effect outward expansion of the lock fingers 59 into an annular channel or internal groove 60 formed within the body J. This groove 60 has an outer downwardly and outwardly flaring wall 61 and a lower substantially horizontal wall 63 which, in the illustrative embodiment, is slightly downwardly and inwardly inclined from a true horizontal plane.

When the casing hanger assembly, including the running tool Z, are to be conditioned to be run into the body J, the seal sleeve 41 will be in place in the mandrel bore 20, closing the parts 39 and 40, and the lower chamber 37 may be pressurized by the application of oil or other fluid thereto under pressure, so as to hold the internal cylinder head 33 of the loading sleeve 28 in an upper position substantially in engagement with the upper piston 27. Such fluid pressure may be passed through a port 37a in the sleeve 28 leading into the chamber 37 from the outside of the loading sleeve 28, and, when the cylinder head 33 is in abutting engagement with the upper piston 27, this port 37a may be closed by a suitable plug 37b which is threaded into an internally threaded bore 27c in the piston 37a in the sleeve 28. Another port 38a leads into the pressure chamber 38 from the outside of the loading sleeve 28 and is adapted to be closed by a plug 38b which is threadedly engaged in a threaded bore 38c in the loading sleeve 28. This port 38a allows the bleeding off of any fluid from within the chamber 38 when the tool assembly is conditioned for running by applying pressure into the oil or other fluid provided hereinabove, and wherein the plug 38b may be installed to close off the chamber 38 from the escape of fluid outwardly from the loading sleeve 28.

Following landing of the hanger body 10 on the shoulder 13 of the body J and cementing of the casing Y in place, as hereinafter described, the sleeve 41 will be pulled from the mandrel passage 20 by a suitable recovery tool, as is well known in the oil well equipment field, and will be recovered from the upper end of the drill pipe 19.

Thereafter, a loading dart, generally denoted at 70 in FIG. 3a, will be lowered through the drill string 19, or dropped therethrough, so as to land upon the internal shoulder 42 within the mandrel passage 20. This dart 70 may be a gate body 71 having a lower cylindrical section 72 provided with a side seal ring 73 adapted to sealingly engage within the mandrel passage 20 below the lower ports 39. The dart body 71 also has an upper cylindrical section 74 provided with side seal rings 75 adapted for sealing engagement within the bore 20 of the mandrel 16 above and below the upper ports 40. The dart body 71, in its lower end section 72, has a transverse passage or passages 76, which communicates with the ports 39 and with a downwardly opening central passage 78 leading into the mandrel bore 20 at the bottom of the dart 70. The upper cylindrical section 74 of the dart 70 has a suitable number of radial passages or ports 79 communicating with the ports 40 and with a likely downwardly extending passage 80 which open upwardly into the mandrel bore 20. At its upper end, the body 71 of the dart 70 has a fishing neck 81 provided with an enlarged head 82, which has a downwardly facing shoulder 83, whereby the dart 70 may be engaged by a suitable fishing tool (not shown) and pulled from the mandrel passage 20 upwardly through the drill pipe 19, when desired.

With the dart 70 in place, as shown in FIG. 3a, the lower groove section 56 between the piston 26 on the mandrel 16 and the internal cylinder head 33 of the loading sleeve 28 may exhaust into the mandrel passage 20 below the dart, and the upper chamber 38 between the loading sleeve head 33 and the mandrel piston 27 is in communication with the mandrel passage 20 above the dart. Therefore, fluid under pressure may be sup-
applied to the chamber 38 through the ports 80, 79 and 40, so as to apply fluid pressure to the head 33 to force the loading sleeve 28 downwardly, the liquid in the lower chamber 36 exhausting through the passages 79, 76, 78. Such downward movement of the loading sleeve 28 will cause corresponding downward movement of the seal support ring 50 and the deformable seal means 55 carried thereby, causing engagement of the deformable metal lock fingers 59 with an inclined or conical expander surface 59a of the portion of the hanger body 10 providing the supporting shoulder 12, which will effect outward expansion and deflection of the lock fingers 59 into the channel 69 of the body 10. The application of further and increased pressure in the chamber 38 will shear the pin 52 and contact the shoulders 54, 53, further downward movement of the support ring 50, following outward deflection or deformation of the lock fingers 59, causing forestalling of the undulated sleeve section 56 and movement of its crests toward the walls 10a, 10b of the hanger bodies 10 and 10, and deformation of the elastomeric body 57 into tight sealing contact with the opposing cylindrical walls 10c and 10d of the hanger body 10 and the outer hanger body 10.

The lock fingers 59 and the undulated sleeve portion 56 of the seal means 55 may be composed of mild steel or other malleable material, which, when expanded as illustrated in FIG. 3b, will be deformed beyond their elastic limit and will retain their deformed shape. Thus, the undulated section 56 of the seal means 55 will be so deformed so as to effect virtual metal-to-metal contact between the inner crests 56a and the outer crests 56b of the undulated sleeve section 56. Under these circumstances, the elastomeric material 57 will fill the spaces between the undulations to assist in the prevention of leakage. A slight thickness of elastomeric material might be trapped between the crests 56a, 56b and the cylinder walls 10a, 10b.

The sealing relation between the inner crests 56a and the outer crests 56b of the undulated seal sleeve section 56 is more particularly illustrated in FIG. 5, in which the elastomeric material 57 is also shown as being caused to extrude into and fill the spaces between the adjacent undulations.

As seen in FIG. 6, a modified seal construction is illustrated in which an undulated seal sleeve section 156 is illustrated, having at least one inner crest 156a and at least one outer crest 156b deformed, in response to axial compressive force applied thereto, into tight sealing engagement with the opposing cylinder walls 10a and 10b. The undulations or corrugations in either of the seal sleeves 56 or 156 are circumferentially continuous, so that the inner crests 56a or 156a and the outer crests 56b or 156b, as the case may be, will effect circumferentially continuous inner and outer sealing engagement with the opposed cylindrical walls.

In the use of the apparatus, the casing hanger assembly, with the loading sleeve 28 in the upper position of FIGS. 2a and 2b and with the sealing sleeve 41 in place, is connected to the threaded pin 18 of the drill pipe 19, so as to be lowered through the body of water into sealing engagement with the shoulder 13 in the previously set hanger body or casing J. Thereafter, a circulating fluid may be displaced downwardly through the drill pipe 19, passing through the mandrel passage 20 and downwardly into the casing Y, thence upwardly through the annulus 21 and then flowing through the ports 22 of the hanger body 10, upwardly through the seal means 25 into a space between the mandrel 16 and the loading sleeve 28. Below the piston 26 on the mandrel 16, circulating fluid will pass through ports 28a externally of the loading sleeve 28 and thence upwardly into the space between the loading sleeve 28 and the casing hanger body J.

Following the circulation of suitable well conditioning fluid for the desired period of time, a quantity of pumpable cement slurry may be displaced downwardly through the pipe 19 behind the circulating fluid and may follow a similar course until the quantity of cement slurry has been displaced to fill or substantially fill the annulus 21. Thereafter, a suitable recovery tool will be run into the pipe 19 and engaged with the flange 47 of the seal sleeve 41, and the seal sleeve 41 recovered. The dart 70 will then be dropped into the pipe 19, or, if necessary, run into a spaced position within the mandrel 16 so as to allow the application of fluid pressure to the upper pressure chamber 38 and the exhaust of the lower chamber 36. In response to the application of such fluid pressure in the upper chamber 38, the loading sleeve 28 will be forced downwardly, moving the seal means 25 and the anchor means 23 downwardly, effecting the outward deformation of the lock fingers 59, as previously described, and also effecting axial and circumferential deformation of the metallic undulated seal ring 56 and the elastic body 57, if the seal ring includes such elastomeric material, the shear pins 52 being disrupted prior to application of maximum pressure to the cylinders 28, 33 in effecting a leak-proof seal. The application of appropriate fluid pressure in the chamber 38 will complete expansion of the sealing means 25 and locking of the fingers 59 in the groove 60, whereupon the entire running tool Z will be free for recovery from the hanger body 10.

In order to recover the running tool Z, the running string of pipe will be rotated to the right to disconnect the left-hand threaded connection between the flange 15 of the tool mandrel 16 and the internally threaded section 14 of the hanger body 10. When the left-hand threaded connection is loosened, upward movement of the running string 19 will move the tool mandrel 16 upwardly until the piston 26 thereon engages the head 33 of the loading sleeve 28 to lift the latter, permitting the entire assembly to be moved upwardly from the casing head or hanger body J, minus the hanger body 10, and the packed-off and anchored seal means 25. Prior to elevating the running tool Z, it is desirable to remove the dart 70 from the mandrel 16 to permit the fluid in the drill pipe 19 to drain during its elevation to the drilling rig.

1. In well bore casing apparatus for supporting an inner string of casing in an outer string of casing supported by an outer casing hanger providing a seat: an inner casing hanger body including a body portion engageable with said seat, a mandrel adapted to be connected to a running string of pipe, means releasably connecting said mandrel to said body, seal means adapted to be displaced by said pipe means, said mandrel is moved in response to pressure in said pipe means for applying fluid pressure to said inner string of casing.

2. In well bore casing apparatus as defined in claim 1; said seal means further comprising an annular body of elastomeric material in which said ring is embedded.

3. In well bore casing apparatus as defined in claim 1; and means for shifting said actuator means including piston and cylinder means on said mandrel and said actuator means defining a pressure chamber, and means for applying fluid pressure to said chamber to move said actuator means.

4. In well bore casing apparatus as defined in claim 1; anchor means movable on said mandrel by said actuator means and engageable with said outer casing hanger.

5. In well bore casing apparatus as defined in claim 1; anchor means movable on said mandrel by said actuator means and engageable with said outer casing hanger, said anchor means being connected to said seal means and movable therewith.

6. In well bore casing apparatus as defined in claim 1; anchor means movable with said outer casing hanger body responsive to movement of said actuator means longitudinally of said mandrel, said anchor means having a plurality of circumferentially spaced longitudinally extended lock fingers, said outer casing hanger having a recess for receiving said fin-
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In well bore casing apparatus as defined in claim 12; said seal means including an axially deformable metallic ring of axially undulate form having inner and outer annular portions respectively inwardly and outwardly deformable into sealing relation with said opposing walls upon axial deformation of said ring, and annular body of elastomeric material in which said ring is embedded and deformable therewith into sealing engagement with said opposing walls.

In well bore casing apparatus as defined in claim 12; said seal means including an axially deformable metallic ring of axially undulate form having inner and outer annular portions respectively inwardly and outwardly deformable into sealing relation with said opposing walls upon axial deformation of said ring, ring and annular body of elastomeric material in which said ring is embedded and deformable therewith into sealing engagement with said opposing walls.

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