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(54) IMPROVEMENTS IN OR RELATING TO A SEAL ADAPTOR ALIGNMENT MEANS FOR OFF-SHORE SUBSEA WELL OPERATIONS

(71) We, SOCIETE NATIONALE ELF AQUITAINE (PRODUCTION), of Tour Aquitaine, 92400 Courbevoie, France, do hereby declare this invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to a seal adaptor for interconnecting in sealed relation fluid passageways in a tubing hanger with corresponding passageways in a safety tree assembly, said tubing hanger being landed by a landing tool and landing technique whereby said tubing hanger is precisely angularly indexed in a subsea wellhead assembly.

In offshore subsea well operations, it is desirable to conduct many of the operations at great depths and without diver assistance. Such well operations at any depth require precise remote control of equipment. In U.S. Patent No. 4,120,632 a subsea station is described which provides wellhead, production, and control modules or assemblies which may be assembled with the subsea station without diver assistance and by use of remote control means. Such a subsea station includes guide posts to which may be connected guide lines by remote control means to facilitate the lowering of equipment along such guide lines and provided with cooperable guide tubes to initially locate and position such lowered well equipment. Such well equipment may include a tubing hanger to be assembled with a well casing or a wellhead assembly at the subsea station, the tubing hanger including fluid conducting passageways for fluid control circuits and annulus lines. Such fluid conducting passageways must be connected with corresponding fluid conducting passageways carried by adjacent well equipment such as a safety tree assembly for production of the well. Fluid interconnection of such passageways requires precise alignment both axially and angularly to avoid leakage and also to avoid damage to tubular nipple members providing a coupling interconnection between two adjacent well members.

Prior proposed means for connecting fluid passageways in two adjacent well members have usually included an arrangement whereby divers or remote control robots may accomplish such a connection. Under diver or robot assistance, the ends of the well members to be interconnected in fluid conducting relationship were often difficult to precisely align and index, and when such misalignment occurred, damage to the seals and the connecting members might occur. At relatively great water depths, such prior methods and constructions used to accomplish such assembly were time-consuming and difficult.

According to one aspect of the invention, there is provided an adaptor arranged to connect and align two well members having fluid conductive passageways with said passageways connected in sealed relationship, comprising: a body member having an inner hollow cylindrical portion with a throughbore therein, at least two part-cylindrical segments concentrically spaced around said inner cylindrical portion, said segments having an axial length greater than the length of said inner portion; said body member having a passageway located between at least one of said segments and said inner portion and adapted to receive a tubular member whose axial length is less than the length of said inner portion.

According to another aspect, apparatus is provided for interconnecting a tubing hanger with well equipment there-above, said tubing hanger including a mandrel end provided with fluid conducting passageways and said well equipment including a member having fluid conducting passageways to be indexed, aligned, and

placed in communication with said passageways in said mandrel end, comprising: an adaptor in accordance with the preceding paragraph secured to said well equipment member; said adaptor including spaced arcuate segments extending axially toward said mandrel end; said mandrel end including axially extending recesses to receive said segments in one predetermined position; and at least one tubular member carried by said adaptor radially inwardly of said segments, the or each tubular member having a length less than the length of said segments and being located for reception in a fluid conducting passageway in said mandrel end in only said one predetermined position, the difference in length of the or each tubular member and said associated arcuate segment restricting engagement of said tubular member with said mandrel end until said one position is determined.

The invention provides means for accomplishing precise coaxial and angular alignment of one or more fluid conducting passageways in adjacent well members to be interconnected in fluid communication.

An advantage of the adaptor of the invention is that tubular fluid conducting nipple members carried thereby are arranged with respect to the adaptor to protect said tubular nipple members against damage during assembly of the adaptor with a tubing hanger mandrel.

Other features and advantages of the invention will become apparent from the following description of a preferred embodiment thereof, by way of example only, with reference to the accompanying drawings, in which:—

Figure 1 is a fragmentary elevational view of a tubing hanger suspended from a pipe string prior to being landed in a well casing;

Figure 2 is a fragmentary elevational view, partly in section, showing a portion of the landing tool located above the portion of the pipe string shown in Figure 1;

Figure 3 is a fragmentary enlarged sectional view of the upper portion of the tubing hanger within a well casing in landed position and preparatory to retrieving the landing tool;

Figure 4 is an enlarged fragmentary view illustrating another step in the retrieval of the landing tool;

Figure 5 is an enlarged fragmentary view taken in the plane indicated by line V—V of Figure 3;

Figure 6 is a fragmentary sectional view showing an adaptor in use to facilitate indexing and aligning of a tree assembly with the tubing hanger;

Figure 7 is a fragmentary sectional view showing the adaptor member and a portion of a tree assembly to which the adaptor member is connected;

Figure 8 is a bottom view of Figure 7; and

Figure 9 is a perspective view of a top end of a tubing hanger including alignment means of this invention.

Generally speaking, a landing tool 20 as shown in Figures 1 and 2 provides a technique for landing a tubing hanger 22 in a well casing 23, Figures 3 and 6, in connection with the completion of a well hole for production. Landing tool 20 may be readily retrieved after completion testing. After such retrieval, the tubing hanger may be connected to a safety tree assembly through an adaptor member 24 in accordance with the invention for indexing and aligning fluid conducting passageways on the safety tree assembly and on the tubing hanger in such a manner that tubular nipple members 112 (Figures 6 to 8) are precisely and accurately guided into proper relationship which the passageways in the upper end of the tubing hanger.

As shown in Figures 1 and 2, landing tool 20 is adapted to carry a tubing hanger 22 which is provided with suitable fluid conducting passageways therethrough for annulus lines and for fluid control lines. Tubing hanger 22 may include a plurality of circumferentially arranged latches 27 for interlocking engagement with well casing 23 in well-known manner. As best seen in Figure 3 and 6, tubing hanger 22 may be landed at 28. Upper end of tubing hanger 22 includes a mandrel end 29 which is received within an internally threaded lower skirt 30 of the landing tool 20.

Landing tool 20 includes a landing tool stinger pipe portion 32 which extends upwardly, Figure 2, for internal threaded engagement with the lower end of a sleeve member 33 initially secured against rotation by a shear pin 34 which interconnects a lower sub 35 which is threaded at 36 to a bearing swivel housing 37 which carries a swivel base 38. Between swivel base 38 and the swivel housing is provided a ball bearing antifriction means 39 to permit relative rotational movement between base 38 and bearing swivel 37. Cap screw 40 holds base 38 in assembly with swivel 37, the inner end of screw 40 being received in annular groove 41 on base 30.

Lower sub 35 is threadedly connected to upper sub 42 which may be connected to pipe string 43 which extends to a vessel having a derrick, not shown, at the water surface. Sleeve member 33 has threaded engagement at 44 with the upper end of lower sub 35 and includes an upwardly directed sleeve extension 45 providing a selected length of external threads 46 to permit axial movement of pipe stinger portion 32 under certain rotational

conditions as later described. Below base 38 of the swivel means 37, the landing tool body 50 includes a relief portion 51 which provides a ledge 52 having a recess 53 within which is pivotally mounted a latch 54. Latch 54 is mounted about a vertical axis or an axis parallel to the axis of the landing tool as indicated at 55 and is normally biased outwardly by springs 56. The latch 54 may be retained in recess 53 by a retainer plate 57 secured on opposite sides of recess 53 by screw bolts 58. Latch 54 is shaped to limit rotation of the landing tool body in a clockwise direction as shown in Fig. 5 and to allow its rotation in a counterclockwise direction.

In the method of landing a tubing hanger by a landing tool 20 as above described, tubing hanger 22 is threadedly connected to the lower skirt 30 of the landing tool by buttress threads 60 which resist rotation in the presence of tension forces acting on the threaded connection. The landing tool 20 is lowered by pipe string 43 until the swivel base 38 is seated as at 61 on a pair of rams 62 which may be provided on a blow out preventor located adjacent the well hole. Rams 62 embrace pipe string portion 32 with a relatively loose sliding fit. Rams 62 are brought into embracing position after body member 50 of the landing tool 20 has passed therebelow.

In such position of the landing tool and the tubing hanger 23 carried thereby, the tubing hanger is angularly oriented with respect to the landing tool 20 by lock piston means 70 as later described.

After base 38 has landed upon rams 62, the pipe string 43 may be rotated in one direction, for example the clockwise direction, thereby causing the landing tool body 50 to rotate to the right and causing the lock dog 54 to bear against the internal surface 65 of the casing wall 66 until dog 54 engages a vertically extending slot 67 in the casing, dog 54 having been urged thereinto by biasing spring 56. Clockwise rotation of the landing tool body is thereby stopped.

To advance the tubing hanger downwardly into its landed position, shear pin 34 is now sheared by further clockwise rotation of the pipe string, since rotation of the body of landing tool 20 is now prevented by lock dog 54. Once pin 34 has been sheared, the pipe string 43 is rotated in the opposite or anticlockwise direction or towards the left. Such rotation will cause the now nonrotatable landing tool body 50, pipe stinger portion 32 and the extension 45 to be advanced downwardly because of the threaded engagement at 44 with the now rotatable subs 42 and 35. Landing tool 20 advances downwardly until the tubing hanger is landed at 28 and the outwardly biased latches 27 engage the well casing to lock said tubing hanger in its selected position.

During landing of the tubing hanger and in landed selected position of the tubing hanger, the landing tool 20 is locked to the tubing hanger against relative rotation by means of a ported lock piston 70 which has a lower end 71 extending into the upper enlarged passageway 72 of a passageway for fluid 73 provided in the tubing hanger for control or annulus purposes. Upper end of lock piston 70 extends into an enlarged bore 74 in tool 20, the bore being provided with a lock ring 75 to limit movement of the lock piston 70 in an upward direction under tool retrieval operations. Lock piston 70 includes an upper piston head 77 provided with suitable O rings 78 for sealing engagement with bore 74. A biasing spring 79 normally urges the lock piston 70 upwardly, such upward movement of the lock piston 70 being restrained by a shear pin 80 engaged in an annular groove in the piston head 77.

After conducting certain tests, landing tool 20 is retrieved by the following procedure. It will be noted landing tool 20 includes a slidable sleeve 83 provided in the central throughbore or passageway of the landing tool. Sleeve 83 is provided with a pair of O rings 84 and with an annular groove 85 which is engaged by a shear pin 86 extending through body 50 and having its exterior opening sealed with a plug 87. Shear pin 86 holds sleeve 83 in the position shown in Figure 3 in which sleeve 83 blocks a port 88 extending between the central passageway in the landing tool and the piston bore 74.

In the landing tool retrieval operation, a dart 90 may be dropped down the pipe string 43 and into the throughbore of the landing tool for final seating in the sleeve 83. Dart 90 may be made of solid material and plugs the opening in sleeve 83 which normally permits passage of fluid through the pipe string. Pressure fluid may now be applied through the central passageway of the pipe string 43 and landing tool 20 to cause the shear pin 86 to shear and release sleeve 83 so that it may slide downwardly into seated position at 92 as shown in Figure 4. In this seated position of sleeve 83 and dart 90, port 88 is exposed and open to pressure fluid which now enters the lock piston bore 74 below piston head 77. The pressure fluid acts upwardly against the piston head 77 and causes shearing of pin 80 which releases the lock piston which is now biased upwardly until it is seated against the lock ring or retainer 75. In this upper position the lower end 70a of the lock piston is withdrawn from the passageway 73 to thereby permit rotation of the pipe string to cause the threaded sleeve member 33 to be

threadedly driven upwardly and thus applying a lifting force to the landing tool 20. Rotation of the landing tool is permitted by the cammed surface of the lock dog 54 and by the disengagement of the lock piston 70 with the tubing hanger. Landing tool 20 may be unthreaded from the mandrel threads 60. The upper end of the landed tubing hanger-or the tubing hanger mandrel 29 is accessible and is available for further well operations.

The further well operations indicated above include the interconnection of the mandrel end 29 of the tubing hanger to a safety tree assembly, only a bottom portion of which is shown, for continuous production operation of the well. As best seen in Figure 6, 7 and 8, tubing hanger 22 is in a selected fixed nonrotative relationship in the well casing or wellhead. A safety tree assembly fragmentarily and generally indicated at 100 is provided with a central passageway 101 and control and annulus passageways, only one of which is illustrated in Figure 6 and identified as passageway 102. It will be apparent that the fluid conducting passageways on the safety tree assembly 100 should be indexed and precisely aligned and sealed so that proper control of well hole operations can be made.

The present invention provides an adaptor means 24 allowing two such well members to be connected in sealed relation, the adaptor means including a body member 105 providing with an inner hollow cylindrical portion 106 having a central throughbore 107 which defines a longitudinal axis. At spaced intervals along the outer peripheral margin of body member 105 there are provided elongated part-cylindrical or arcuate segments 108, 108a and 108b, said arcuate segments extending in the same direction as inner portion 106. Each arcuate segment 108, 108a and 108b has a length which is greater than the length of inner portion 106. Each arcuate segment includes inner and outer beveled edges 109 and 109a, respectively, serving as guide means as later described. Each arcuate segment 108, 108a, 108b is formed about the axis of inner portion 106 and each subtends an angle of different magnitude than the angle subtended by an adjacent arcuate segment. Alternatively each arcuate segment 108 has a chord of different length than the chord of each of the other arcuate segments.

Body member 105 is provided with bores 110 provided with upwardly facing countersunk shoulders 111 for reception of tubular nipple members 112. Each nipple member 112 has a collar 114 seated in the countersunk recess 111 for positioning tubular member 112 in body 105. As noted in Figure 8, each tubular member 112 has an axis which lies on a radian within the arc subtended by its associated arcuate segment 108. Each tubular member 112 has a top end 115 provided with seal O rings 116 for sealing engagement with an enlarged counterbore in safety tree assembly 100. The bottom end of tubular member 112 includes a plurality of O rings 117 and a beveled bottom edge 118 for reception within the corresponding passageway in the mandrel end 29 of the tubing hanger. The length of tubular member 112, which extends parallel to the arcuate segments 108 and the inner portion 106, is less than the lengths of portion 106 and segments 108. The lower end of tubular member 112 is protectively spaced longitudinally within the extremities of portion 106 and segments 108 and laterally therebetween.

The mandrel upper end 29 is provided on its external surface with longitudinally extending recesses 120, 120a, 120b corresponding to the length and arcuate configuration of respective segments 108, 108a and 108b. Fluid passageways in the mandrel end 29 and in the safety tree assembly 100, to be joined by the tubular nipple members 112, are also correlated to the respective arcuate segments 108, 108a, 108b and recesses 120, 120a, 120b. Thus, proper angular alignment of the assembly 100 and mandrel 29 is assured by the proper mating of the arcuate segments and recesses.

Adaptor means 24 is secured to the safety tree assembly by suitable circularly spaced screw bolts 121 located in peripheral marginal portion of body member 105 between ends of adjacent arcuate segments 108, 108a and 108b. The interface between the safety tree assembly 100 and the adaptor means 24 is provided with suitable annular seals 122.

When the safety tree assembly is to be installed and connected to the tubing hanger, the adaptor member 24, secured on the bottom face of the safety tree assembly, is lowered along the axis of the safety tree assembly and the tubing hanger. It will be understood that such lowering of the safety tree assembly may be done by well-known guide lines and guide sleeve and post arrangements, such as shown and described in U. S. Patent 4,120,632.

As the adaptor member 24 moves into proximity with the upper end of the mandrel end 29, the adaptor member may be turned by turning the pipe string carrying the safety tree assembly and indexed into proper relationship with the mandrel end 29 by engagement of corresponding mating arcuate segments and recesses on the mandrel end. In the event of angular or azimuth misalignment, bottom edges of the arcuate segments 108, 108a, 108b will

contact the upper end face of mandrel 29 at areas between the segment receiving recesses 120, 120a, 120b on the mandrel end and will thereby block further lowering of the safety tree assembly. In such misalignment condition, it will be noticed that the lower ends of the tubular nipple member 112 are spaced from tubing hanger mandrel end 29 and are thereby protected from damage which might be caused by contact under such misalignment. As the adaptor member and safety tree assembly is turned, it will be also apparent that the arcuate segments 108, 108a, 108b will not enter the arcuate recesses 120, 120a, 120b on the mandrel end unless the corresponding mating recess is in alignment with its arcuate segment. When such angular alignment is achieved and the segments are aligned with their corresponding respective arcuate recesses, the adaptor member may be moved axially into assembly with the mandrel end 29 and the arcuate segments fully received in their corresponding recesses.

During such final assembly stages, it will be apparent that the lowest portions of the arcuate segments 108, 108a and 108b provide azimuth or angular alignment of the tubular nipple members 112 with their respective passageways, before the lower ends 118 of members 112 enter their respective passageways in the mandrel end and thereby provides additional coaxial alignment of the adaptor means 24 with mandrel end 29. When the adaptor member has been properly indexed, aligned with respect to both azimuth and longitudinally axis, the tubular members 112 will be coaxially aligned with their respective passageways in the mandrel end for precise entry without damage.

Figure 6 illustrates final assembled relationship of a safety tree assembly 100 with mandrel end 29 utilizing an adaptor means such as 24. Arcuate segment 108 is fully seated in its corresponding recess 120 in the mandrel end 29 and inner portion 106 is received within the upper slightly enlarged portion 123a of the throughbore 123 of the tubing hanger 22. Control of annulus passageway 73 is in sealed communication with passageway 102 of the tree assembly 100 by the passageway provided in the tubular nipple member 112.

While adaptor means 24 has been described with respect to its use in final stages of preparing the wellhead for production, it will be understood that such adaptor construction may be readily used during other stages of preparation of the wellhead, as for example, the completion test stage. It will also be understood that the construction of the adaptor means and the mandrel end may be used in other installations when necessary to precisely coaxially and angularly align or register two members to be connected by remote control means. The sealed interconnection of fluid conducting lines is a primary example of this invention; the coaxial and angular alignment features of the invention may be used in the interconnection of other types of lines.

Landing tool 20 provides a means for precise placement and installation of a tubing hanger or similar well tool equipment in a subsea wellhead or well casing in precise preselected angular or azimuth orientation of the tubing hanger in the casing. Such precise positioning of the tubing hanger includes precise location of the recesses 120, 120a and 120b in the mandrel end 29 and thereby determines the location of the entry to the control and annulus passageways in the tubing hanger. Thus, when the tree assembly with adaptor means 24 attached thereto is lowered for assembly with the tubing hanger, the orientation of the arcuate segments is in approximate alignment therewith. Mating of the arcuate segments with the mandrel recesses is accomplished only after the tree assembly and adaptor means carried thereby are positioned for precise interengagement with the mandrel end 29 by slight turning of the adaptor means. While seeking precise alignment, the interconnecting nipple members 112 are in a protected position wherein the seals carried thereby will not be subject to abrasion and possible damage.

From the foregoing description, it will be seen that an adaptor for aligning two members to be connected in coaxial sealed relationship is provided in which the adaptor includes an adaptor body member having an inner central portion with a throughbore and of preselected length, at least two-part cylindrical or arcuate segments spaced radially outwardly of said inner portion and in concentric relation thereto, said arcuate segments having a length greater than the length of the inner portion; and tubular nipple members carried in passageways in said body member, said tubular members having a length not greater than the length of the inner portion or the segments and lying on a radian between a segment and the inner portion. The arcuate segments each subtend a different angle and are slidably, precisely received in corresponding arcuate recesses provided on a mandrel end of a well tool for precise alignment of the tubular nipple member with a passageway in the well tool. There is also described a landing tool and landing technique for locating a tubing hanger in a wellhead assembly in a precise position whereby said seal adaptor means

may be properly aligned and mated with said tubing hanger as well as a landing tool and landing technique in which a tubing hanger is supported above its landed position while being angularly oriented, and when once oriented is lowered into landed position without turning or loss of such angular orientation.

Reference should be made to copending Patent application No. 7914295 (Serial No. 1591863), divided from the present application, which describes and claims some features of the apparatus described herein.

WHAT WE CLAIM IS:—

1. An adaptor arranged to connect and align two well members having fluid conductive passageways with said passageways connected in sealed relationship, comprising: a body member having an inner hollow cylindrical portion with a throughbore therein, at least two part-cylindrical segments concentrically spaced around said inner cylindrical portion, said segments having an axial length greater than the length of said inner portion; said body member having a passageway located between at least one of said segments and said inner portion and adapted to receive a tubular member whose axial length is less than the length of said inner portion.

2. An adaptor as claimed in claim 1 wherein at least two of said part-cylindrical segments subtend arcs of different length.

3. An adaptor as claimed in claim 1 or claim 2 wherein a tubular member is located in the or each passageway in said body member, the or each tubular member having a length less than said inner portion and said segment.

4. An adaptor as claimed in claim 3 wherein the or each tubular member has an axis lying on a radian lying within the angle subtended by said part-cylindrical segment.

5. An adaptor as claimed in claim 3 wherein the or each tubular member includes a portion extending from said body member for sealing engagement with one of said members to be connected; and means carried by said body member for securing said adaptor to said one connector member.

6. Apparatus for interconnecting a tubing hanger with well equipment thereabove, said tubing hanger including a mandrel end provided with fluid conducting passageways and said well equipment including a member having fluid conducting passageways to be indexed, aligned, and placed in communication with said passageways in said mandrel end, comprising:

an adaptor in accordance with any of claims 1 to 6 secured to said well equipment member; said adaptor including spaced arcuate segments extending axially toward said mandrel end; said mandrel end including axially extending recesses to receive said segments in one predetermined position; and at least one tubular member carried by said adaptor radially inwardly of said segments, the or each tubular member having a length less than the length of said segments and being located for reception in a fluid conducting passageway in said mandrel end in only said one predetermined position, the difference in length of the or each tubular member and said associated arcuate segment restricting engagement of said tubular member with said mandrel end until said one position is determined.

7. Apparatus as claimed in claim 6 wherein each arcuate segment has a chord length matched by the chord length of only one of said mating recesses on said mandrel end.

8. Apparatus as claimed in claim 6 or claim 7 wherein each arcuate segment has a predetermined arc width different than an adjacent segment, the or each tubular member having an end portion extending above said body member.

9. Apparatus as claimed in any of claims 6 to 8 wherein each of said arcuate segments includes bottom bevelled edges for guidance of said segments into engagement with said mandrel end.

10. An adaptor arranged to connect and align two well members having fluid conductive passageways with said passageways connected in sealed relationship, substantially as herein described with reference to the accompanying drawings.

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may be properly aligned and mated with said tubing hanger as well as a landing tool and landing technique in which a tubing hanger is supported above its landed position while being angularly oriented, and when once oriented is lowered into landed position without turning or loss of such angular orientation.

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2. An adaptor as claimed in claim 1 wherein at least two of said part-cylindrical segments subtend arcs of different length.

3. An adaptor as claimed in claim 1 or claim 2 wherein a tubular member is located in the or each passageway in said body member, the or each tubular member having a length less than said inner portion and said segment.

4. An adaptor as claimed in claim 3 wherein the or each tubular member has an axis lying on a radian lying within the angle subtended by said part-cylindrical segment.

5. An adaptor as claimed in claim 3 wherein the or each tubular member includes a portion extending from said body member for sealing engagement with one of said members to be connected; and means carried by said body member for securing said adaptor to said one connector member.

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