REMOTE UNDERWATER FLOWLINE CONNECTION

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ABSTRACT
A method and apparatus related thereto for remotely connecting flowlines to an underwater wellhead. A connector support cradle is mounted to a well conductor. A guide system is provided to guide into place a remotely operable underwater tree, flowline loops, and connector tree hub which is connected to the flowline loops. The tree hub is guided and latched into one end of the support cradle. Then one end of the underwater flowlines attached to a flowline connector hub is lowered with the aid of the guide system into engagement with the opposite end of the support cradle. Finally, a hydraulically operable connector is guided into the cradle between the tree hub and flowline hub. Pressure is supplied to the connector through conduits to cause the connector to sealingly engage the hubs providing flow communication between the tree and flowlines.

50 Claims, 21 Drawing Figures
REMOTE UNDERWATER FLOWLINE CONNECTION

BACKGROUND OF THE INVENTION

1. Field of the Invention
This invention relates to petroleum production methods and apparatus and more particularly to methods and apparatus for remotely connecting underwater flowlines to underwater production trees.

2. Description of the Prior Art
Underwater drilling for oil and gas has been practiced for a good many years. However, completing these wells with an underwater wellhead assembly near the ocean floor has become common only in the past few years. Underwater wellhead assemblies offer the advantage of safety from collision by oceangoing vessels and from damage by hurricanes, high winds, and ocean currents.

However, underwater well completions present many problems. One such problem is the connection of production flowlines to the underwater production tree. Until recently this was accomplished by divers. However, divers are limited to relatively shallow water. Such installations require diver assistance any time it becomes necessary to pull the production tree or to disconnect the flowline for any other reason.

The desire to drill in deeper water and to operate without diver assistance has led to development of remotely operable underwater connectors such as the one disclosed in U.S. Pat. No. 3,233,666. These connectors allow remote connection and separation of flowlines and production trees.

Generally these connectors are hydraulically or pneumatically engangeable devices affixed to the production tree which is also remotely engaged in the wellhead. As is the case in any piece of equipment with working parts, occasionally the connectors malfunction and require removal for repair. With the presently known connectors, this requires the removal of the production tree also, which is quite a costly operation.

It is also quite difficult to design a connector for easy handling of the flowlines during connection operations. Since the flowlines tend to lay rigidly along the ocean floor they exert large forces at their ends when the ends are raised or lowered in the water. This presents difficult alignment problems for the connectors presently in use.

SUMMARY OF THE INVENTION
The present invention provides methods and apparatus for remotely connecting underwater flowlines to an underwater wellhead independent of wellhead and flowline installation. In the present invention support means for connection equipment is lowered along with the well conductor casing in the initial drilling stages. The wellhead, production tree and flow loops attached to the connection hub are remotely guided and lowered into place and installed as completion progresses. Then the ends of flowlines attached to another connection hub are remotely lowered into position in the support means. A special tool permits a downward force to be applied at such a point in relationship to the flowline ends so that the moment produced by flowline weight is counterbalanced for easier alignment and attachment to the support means leaving a space between the end of the flowline hub and the end of the flow loop or tree hub. Finally a connector is remotely lowered into this space and actuated from a remote power source to engage both hubs providing fluidtight flow communication between the flow loops and flowlines.

All of the connection parts which are normally susceptible to malfunction are contained in the connector. Thus, if necessary, the connector, independently of the flowlines and wellhead, may be remotely disengaged and removed for inspection, repair, or replacement. In addition, the production tree and other wellhead equipment may be removed or worked on without disturbing the flowline or vice versa.

The present invention therefore, incorporates the advantages of remote flowline connection without the usual disadvantages of removing either or both the production tree and flowline when connector repair is necessary. It also allows independent placement and removal of both the production tree and flowlines without disturbing the other.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of an underwater wellhead connected to underwater flowlines by a connector in accordance with one embodiment of the invention;
FIG. 2 is a cut-away perspective view of one embodiment of support means utilized in the invention;
FIG. 3 is a vertical sectional view of a latch means employed in the invention;
FIG. 4 is a top plan view of a flowline hub which may be used in the present invention;
FIG. 5 is a vertical sectional view of the hub shown in FIG. 4 taken along lines 5-5;
FIG. 6 is a vertical sectional view of the right end of the hub shown in FIG. 5;
FIG. 7 is a representative sectional view of the hub of FIGS. 4 and 5 taken along line 7-7 of FIG. 5;
FIG. 8 is a perspective view of one embodiment of a guide frame which may be used in the installation of the present invention;
FIG. 9A is an elevational view of the guide frame of FIG. 8 connected to a running tool and a flowline hub similar to the hub shown in FIG. 4;
FIG. 9B is an elevational view in section of a flowline joint which may be used in the present invention;
FIG. 9C is a vertical cross section of the joint shown in FIG. 9B;
FIG. 10 is a detailed vertical section of the running tool shown in FIG. 9A;
FIG. 11 is a vertical end view of the tool of FIG. 10 shown in its relationship with a flowline hub and latch means;
FIG. 12 is a vertical section view of a joint to be connected between a running string and the guide frame of FIG. 9A;
FIG. 13 is an elevational view of the guide frame of FIGS. 8 and 9A connected to one embodiment of a flowline connector of the invention;
FIG. 14 is an exploded perspective view of one embodiment of a flowline connector for use in the invention;
FIG. 15A is a top view, partially in section, of the flowline connector of FIG. 14 shown in a disengaged position;
FIG. 15B is a top view in section of the right hand portion of the flowline connector shown in FIG. 15A in a partially engaged position;
FIG. 15C is a top view similar to FIG. 15B showing the connector in a fully engaged position;
FIG. 16 is a vertical section of a portion of the flowline connector, running neck, and tool of FIG. 13 taken along line 16—16 of FIG. 13; and FIG. 17 is an elevational view of a portion of the running neck and tool of FIG. 16 taken along line 17—17 thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. 1, an underwater wellhead and related equipment is shown for well completion near the ocean floor. A conductor casing 2 is shown with a support base 3 welded thereto. Guide columns 4, firmly affixed to support base 3, extend upwardly from base 3, their axes being parallel to the axis of the well bore. Guide cables 5, attached to the ends of guide columns 4, extend to the surface (not shown) where they are attached to a floating platform during drilling, completion, or workover operations. After completion of the well, cables 5 may be removed or buoyed for future use. If removed they may be reinstalled for future use.

A production tree, designated generally at 10, is shown lowered into position and remotely connected to the well by remote wellhead connection means 20. Several remote wellhead connection means are available. One is described in U.S. Pat. No. 3,186,486. To guide the tree 10 and connection means 20 into position, guide tubes 21 are connected by structural supports 22 to connection means 20. Cables 5 pass through the tubes 21 and initially guide the tree 10 and connection means 20 as they are lowered toward the ocean floor. Bell bottoms 23 provide final alignment as tubes 21 engage guide columns 4. The upper ends of tubes 21 are tapered inwardly to accommodate means for guiding other equipment to be subsequently described.

Production tree 10, as shown, is a dual completion tree. A single completion or other multiple completion may just as easily be performed with the present invention, the dual tree being used only for description purposes. Production tree 10 includes master valves 11, swab valves 12, diverter valves 13, and a valve selector 14 which is connected to a remote control station to control operation of the various valves shown. A valve selector suitable for such use is described in copending patent application U.S. Ser. No. 587,892 filed by John H. Fowler and David P. Herd on Oct. 19, 1966, and assigned to the assignee of the present application.

Connected to the dual strings of production tree 10 are flow loops 25 with wye valves 26 and cross over valve 27. Cross over valve 27 is normally closed. However, during "pigging" operations to clean out flowlines it may be opened to allow reversal of flow in flow loops 25 so a "pig" which has entered the flow loops may be returned to its launching point on shore. Welded to support base 3 is connector support cradle 30 which is naturally lowered into place along with support base 3 and conductor 2 during the early stages of drilling. Supported by cradle 30 is connector tree hub 31, connector flowline hub 32, and flowline connector 33. Flow loops 25 terminate in a threaded connection with tree hub 31. Connected to flowline hub 32 are flowlines 35 which are run to production collection facilities on shore or at a platform some distance away. Connector 33 and hubs 31 and 32 provide flow communication between flowlines 35 and flow loops 25. The cradle 30, hubs 31, 32, and connector 33 comprise the flowline connection means which will be described in more detail.

Referring also now to FIG. 2, a perspective cutout view of the connector support cradle 30 is shown. Base rails 51 and bed plate 52 make up the lower framework. A pair of vertical hub yoke pieces 53 are spaced apart and attached at each end of the cradle to rails 51. A rectangular slot 54 open at the upper end is cut in each yoke piece. Inclined surfaces 55 connect the vertical sides of slot 54 to the upper edge 56 of the yoke pieces. A pair of vertical connector yoke pieces 61 are spaced apart and attached to rails 51 and plate 52. A semicircular cutout presents an upwardly facing curved surface 62. The inner edge of surface 62 is beveled at 63. Lying midway between yokes 61 are channel guide pieces 65, one extending upwardly from each rail 51. Angle iron braces 66, 67, and 68 provide rigidity to the whole cradle assembly. Two hub latches 70 are attached to each hub yoke piece on each end of the cradle facing each other. Metal plates 69 are welded to inclined surfaces 55 to protect the latch housings 70, and to aid in guiding hubs 31 and 32 (FIG. 1) into place within cradle 30.

FIG. 3 is a detail of the entire hub latch assembly to be mounted in latch housings 70. A portion of hub yoke 53 is shown with latch housing 70 in section. The interior of housing 70 is cylindrical and receives helical spring 71, cylindrical latch shaft 72 and thrust ring 73. Attached to the outwardly facing ends of housing 70 is plate 74 which has a hole slightly larger than the diameter of shaft 72 and concentric therewith. Shaft 72 projects through another hole in the inward face of housing 70. O-rings 75, 76, 77 seal the interior of housing 70 against the underwater environment to which it will be subjected. The end of shaft 72 is provided with a latch key 78 which has an upwardly facing inclined surface 79. In its innermost position, key 78 lies within the projection of slot 54. A rectangular object lowered into slot 54 will contact inclined surface 79 causing key 78 to move back toward housing 70 against the force of spring 71. After the object downwardly passes key 78, shaft 72 will spring back, locking the object into place by virtue of horizontal surface 80. The bottom edge of key 78 has a slight lip bevel 82 to aid in removal of the latched in object on camming key 78 out of engagement as will be more fully understood hereafter.

Referring now also to FIGS. 4, 5, 6 and 7 flowline hub 32 will be described. FIG. 4 is a top view of the hub 32. It has cylindrical end portions 81 and 82 connected by a generally square cross section portion 83. Tapped holes 84 are provided for connection of a running and pulling tool to be subsequently described.

From FIG. 5, a sectional view, it can be seen that four identical guide slots indicated generally at 85 are machined, two each at the junctions of portions 81 and 83 and portions 82 and 83. These slots are formed by dihedral surfaces 86, 87 and 88. (See FIG. 6 also). Guide slots 85 aid in guiding and aligning hub 32 into one pair of hub yokes 53 of cradle 30 (See FIG. 2) which will be better understood subsequently.

Dual flow bores 90 and dual hydraulic fluid bores 91 pass longitudinally through the entire length of hub 32. Looking now at FIG. 7, bores 90 and 91 terminate in connection threads 92 and 93 on the outboard end of hub 32. At the inboard end they terminate in counterbores 94 and 95. The opening of each counterbore 94 and 95 is beveled at 96 and 97. Cylindrical portion 81 is
has an integral locking flange 98 and a frustoconical sealing ring counterbore 99 which communicates with counterbores 94 and 95. 

Tree hub 31 (FIG. 1) is a mirror image of flowline hub 32. To install tree hub 31 it would be lowered along with the production tree 10, flow loops 25 being connected to the threads on the inboard side (similar to threads 92 described in flowline hub 32). Tree hub 31 can be rigidly attached at the proper location to tree 10 so that it can be guided into cradle 30 and positioned in rectangular slots 54 of the pair of hub yoke pieces 53 (See FIG. 2) nearest the well bore at the same time remote connection means 20 engages the wellhead. The guide system including columns 4, tubes 51 and cables 5 provide initial alignment. Final alignment is accomplished by means including the dihedral surfaces 86, 87, 88 of guide slots 85 (FIGS. 4, 5 and 6). If desired, hub 31 will be latched in the cradle by the latch assembly affixed to the yoke piece 53 or rigidly attached to the well conductor and base.

The installation of flowline hub 32 requires a special guide frame 100, a perspective view of which is shown in FIG. 8. It includes a triangular frame 101, guide tubes 102 with bell bottoms 103, a box 104 with a fixed cylindrical passageway 105 therethrough and a running string connection cylinder 106. 

In FIG. 9A, an elevation view partially in section, guide frame 100 and running and pulling tool 120 are shown with flowline hub 32 seated in the outboard pair of yoke pieces 53 of support cradle 30 (FIG. 2). Flowlines 35 are connected to hub 32. To install hub 32, guide tubes 102 are placed at the water surface around the two cables 5 which are attached to guide columns 4 nearest cradle 30 (FIG. 1). A running pipe string 107 is connected to cylinder 106 by tool joint 110, to be more fully described subsequently. Running and pulling tool 120 is attached to cylinder 106 at joint 109. Flowline hub 32 is connected to tool 120, which will be more fully described later. Flowlines 35 are connected to hub 32. The whole assembly is then lowered by running string 107 toward the wellhead and support cradle 30. The lowering of flowlines 35 must be coordinated with this operation and may be done from pipeline lay barges or from the drilling vessel itself by use of a plurality of ball joints, to be described later, to impart flexibility to the lines. As the whole assembly descends it is guided by guide tubes 102, cables 5, and running string 107. Nearing bottom, bell bottoms 103 guide tubes 102 onto guide tubes 21. Flowline hub 32 begins to enter yoke pieces 53 and is guided into final alignment by inclined surface 55 and the dihedral surfaces 86, 87, 88 of guide slots 85 in the bottom of the hub (See FIGS. 4, 5, and 6). Since flowlines 35 are exiting a downward force on the right end of hub 32 (as viewed in FIG. 1) there is a tendency to prevent the left end from properly seating in yoke piece 53. However, since running string 107 is offset to the left end of hub 32 a downward force may be exerted to counterbalance the moment exerted by these flowlines. If the hub 32 is not properly aligned this force may cause it to pivot at a contact point on outer yoke 53 into alignment. When hub 32 is properly seated the latching means 70 attached to yokes 53 snap into place locking hub 32 into the cradle (See FIG. 3). Tool 120 may then be released and removed along with guide frame 100 by raising running string 107. 

To reduce the resistance to alignment caused by the moment exerted by the weight of flowline 35 a flexible joint may be used between flowline sections. A suitable joint is shown in FIG. 9B. The joint comprises three basic parts, socket 185, ball 190, and socket coupling 195. 

Socket 185 is provided with threads 186 for connection to a flowline section and external threads 187 for connection to coupling 195. The internal face of joint 185 is machined with a spherically shaped band 188 for mating with ball 190. Lying intermediate of band 188 and cylindrical flow passage 189 is frustoconical surface 189a to allow passage of in-line tools, which may be sent through flowlines from time to time, even though the axes of ball 190 and socket 185 are not concentrically aligned. Connecting spherical band 188 and surface 189a is a series of radial key slots 188a which may be formed by milling into an annular shoulder 188b and cylindrical band 188c (See FIG. 9C). 

Ball 190 has threads 191 for connection to a flowline joint, flow passage 192 and a spherical ball 193 on its inner end. Flow passage 192 enlarges through frustoconical portions 192a and 192b through the interior of ball 193 to cooperate with surface 199a of socket 185 in allowing tool passage during nonalignment. A portion of spherical ball 193 mates with socket surface 188, O-ring seal 194 assures a fluid tight sliding joint. Milling out radial slots 193a between surface 192a and the exterior of spherical ball 193 provides ball 193 with keys which mate with key slots 188a of socket 185 to prevent relative axial rotation of ball 190 with respect to socket 185. This facilitates the operation of screwing the ball joint onto joints of flowline, and decreases the tendency for coupling 195 to work loose. Although the mating keys and key slots of ball 190 and socket 185 prevent axial rotation they do not prevent angular displacement. Thus, the force required to pivot hub 32 and the ends of flowlines 35 about the support yoke is substantially reduced. 

Coupling 195, threaded at 196 to connect to socket 185 and provided with spherical surface at 197, couples all joint pieces together. Frustoconical surface 198, which has a taper of 5° in one preferred embodiment, limits the deflection of the joint to 5° to assure passage of in-line tools. O-rings 199 along with ball O-rings 194 and 194b assure a fluid tight sliding junction. A lubricating port 195a allows joint lubrication and packing for trouble-free service.

To fully understand tool 120, reference is now made also to FIGS. 10 and 11 which show the tool connected to hub 32 in position within yoke pieces 53. Tool 120 is generally cylindrical in shape. It has a cylindrical interior 121 into which a fishing neck 122 projects through a vertical hole 123 on its lower side. Fishing neck 122 is cylindrical and is attached by flange 124 and bolts 125 to hub 32. The tapped holes 84 for bolts 125 are shown in FIG. 4. Passing horizontally through neck 122 perpendicular to plane of page is a cylindrical pin 126 which projects out of each side of neck 122. To allow pin 126 to enter tool 120, vertical slots 127 are machined on interior 121. A frustoconical surface 128 on neck 122 and the upper interior of tool 120 is provided to allow passage of debris which might prevent proper seating of neck 122 in tool 120. 

Neck 122 is held in tool 120 by a piston assembly which includes piston 130, rod 131, circular plate 132, and fork 133. “U” shaped fork 133 which is attached
to plate 132 has a pair of horizontal prongs which pass around neck 122 under the projecting ends of pin 126 to lock hub 32 to tool 120. Piston 130 operates in cylinder 134 to move fork 133 in and out of engagement with neck 122. In the position shown fork 133 is fully engaged. To move the fork and hold it in this position fluid pressure is supplied to cylinder 134 through conduit 135 which forces piston 130 to the right as shown. To disengage tool 120 pressure is applied on the rod side of piston 130 through conduit 136 causing the fork 133 to move to the left, freeing tool 120 to move upwardly from neck 122. Cylinder 134 is closed by annular plug 137. O-rings 138 are provided at necessary sealing points.

A yoke rest 140 provides a support for the left end of tool 120. Latch retractor 141 may be provided on the bottom of tool 120 just inside yoke pieces 53 to cam key 78 of the latching means, mounted in enclosures 70, out of engagement with hub 32. Normally, retractor 141 are only used when hub 32 is being removed and would not be installed during running operations.

Connection elbow 142 and collar 143 are nonrotatingly connected through joint 109 (See FIG. 9A) to the guide frame 100. The axis of collar 143 is the direction of force applied through the running string to counterbalance the moment resulting from the weight of the flowline at the outboard end of hub 32.

Tool joint 110 (See FIG. 9A) can be more fully understood with reference to FIG. 12, which shows the joint 110 connected to guide frame cylinder 106. Tool joint 110 is made up of an upper cylindrical portion 150, an intermediate cylindrical portion 151, and a lower cylindrical portion 152 of decreasing diameters. Upper portion 150 is provided with means such as internal threads 154 for connection to running string 107 (See FIG. 9). Joint 110 is connected to cylinder 106 by threads 155 and has a conduit 156 which, in the position shown, communicates with port 157 drilled in cylinder 106. Halfdog set screws 159 aid in aligning joint 110 in this position by running shoulder 160 of the joint back up against the set screws. For running operations joint 110 is held in this position by shear screw 158. Port 157 is connected by an external conduit 157a to port 135 in tool 120 (See FIG. 10). Thus, fluid pressure may be applied to the left side of piston 130 through the running pipe string.

As stated before, when the flowline hub has been latched in place, to remove tool 120, it is necessary to move piston 130 to the left of the position shown in FIG. 10. To accomplish this, tool joint 110 is screwed further down into cylinder 106 by applying torque to the running string to first shear screw 158 and then turning the running string. Joint 110 will bottom up in cylinder 106 so that conduit 156 now communicates with cylinder port 161 which is connected by another external conduit 161a to port 136 (FIG. 10) on the rod side of piston 130. Bleed port 162 and vent 163 prevent pressure build up under the lower portion of joint 110. Fluid pressure may now be applied from the surface through the running string and joint 110 to release tool 120 from hub 32, as previously explained with reference to FIG. 10. To pull hub 32, the external conduits 157a, 161a would be interchanged so that port 157 is connected to port 136 in tool 120, and port 161 is connected to port 135. The same procedure described for running operations would then be used for pulling operations.

The installation of all equipment shown in FIG. 1 except flowline connector 33 has been described. With tree hub 31 and flowline hub 32 securely installed in cradle 30, it is now necessary to install connector 33 between hubs 31 and 32 to provide flow communication between flowlines 35 and flow loops 25. The installation and construction of connector 33 will now be explained.

To completely understand the installation of connector 33 reference is now made to FIG. 13. For running connector 33, the same guide frame 100 shown in FIGS. 8 and 9 is used. However, tool 120, tool joint 110 and running string 107 shown in FIG. 9 are removed. Instead, a rotating union 300 is installed in the cylindrical passageway through box 104. Running string 107 is now connected by a conventional threaded connection to union 300. Connected to the lower end of union 300 is connector running and pulling tool 320, which is connected also to running neck 203. Running neck 203 is fastened to running sleeve 202, a portion of connector 33. A full description of running and pulling tool 320 and running neck 203 will follow.

With connector 33 attached through tool 320 to guide frame 100 and running string 107 at the water surface, rotating union 300 is shear pinned at 300a to prevent rotation of connector 33, and the whole assembly is lowered toward the underwater wellhead and cradle 30, to position connector 33 for engagement with tree hub 31 and flowline hub 32 (See FIG. 1). Guide cables 5, guide tubes 102, and running string 107 provide initial guidance. As bell bottom 103 reaches tube 21 further alignment is attained which is also aided by running sleeve 202 entering guide channels 65, attached to cradle 30. Final alignment is accomplished by connector yoke pieces 61, retaining ring 229 and the beveled ends 240 of cylinder 200. In this fully supported and aligned position connector 33 may be engaged and disengaged with hubs 31 and 32 as described hereafter.

Looking now at FIG. 14, an exploded view, the components of connector 33 may be seen. The exploded pieces to the left of piece 210 are typical of the pieces which lie in an opposite manner to the right of piece 210.

Connector 33 comprises a cylinder 200 surrounded by annular running sleeve 201 which has a flange portion 202 for connecting to running neck 203 with bolts 204. Running neck 203 and its function will be subsequently described. Three vertical holes 205 are drilled through flange 202 and cylinder 200 to receive fluid nipples 206. O-rings 207 and 208 seal around flange 202 and nipples 206 respectively.

Nipple receptacle 210 has a circular flange portion 211 with a smaller diameter hub portions 212 projecting from each side. Three holes 213 are drilled in rib 211 so that they will line up with holes 205 in sleeve 201 when receptacle 210 is centered inside of cylinder 200. Tapped radial holes 209 are provided in sleeve 201 and cylinder 200 to communicate with flat bottom radial holes 214 in rib portion 211. Half dog set screws 200 may then be inserted to affix sleeve 201, cylinder 200 and receptacle 210 to one another. A pair of flow bores 215 and a pair of hydraulic fluid bores 216 pass longitudinally through receptacle 210. Pressure conduits 217 also pass through receptacle 210. Each one of these
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Conduits 217 is in communication with one of the outside holes 213. Middle hole 213 is in communication with pressure conduit 218 which passes through flange portion 211.

Other components of connector 33 include tube retainer plate 222, pressure ring 223, a set of latch keys 224, latch cylinder 225, a pair of flow tubes 226, a pair of hydraulic tubes 227, and a pair of pressure tubes 228. Also included is retainer ring 229, ram 230, seal ring 231, various bolts, nuts, and O-rings for sealing.

To understand the function of the various components of connector 33 reference is now made to FIGS. 15A, 15B and 15C top sectional views, which show connector 33 seated on connector yoke pieces 61. Tree hub 31 and flowline hub 32 are located in place within the support cradle. Channel guide pieces 65, previously described, are also shown.

Connector cylinder 200 lies between yokes 61 abutting the inner face of each yoke. The ends of cylinder 200 are beveled at 240, cooperating with yoke bevels 63 to aid in alignment of connector 33 as it is installed. Each end of cylinder 200 is threaded at 241 to receive retainer ring 229. Retainer ring 229 provides the bearing surface for supporting connector 33 on the curved surface 62 (FIG. 2) of yoke pieces 61. As previously explained running sleeve 201, cylinder 200, and nipple receptacle 210 are fixedly attached to each other by set screws 220. Running sleeve 201 cooperates with guide channels 65 for initial alignment of connector 33 as it is installed.

A latch cylinder 225 is slidably disposed in cylinder 200 one on each side of receptacle 210. The outside diameter of latch cylinder 225 is slightly less than the inside diameter of retainer ring 229, allowing latch cylinder 225 to slide back and forth within cylinder 200. An annular shoulder 242 is provided to cooperate with retainer ring 229 to retain latch cylinder 225 within cylinder 200. An inner annular lip 243 engages latch keys 244, the function of which will be more fully understood subsequently.

Cylindrical ram 230, pressure ring 233, flow tubes 226, tube retainer plate 222 and hydraulic tubes 227 and pressure tubes 228 (FIG. 14) are slidably disposed within latch cylinder 225 and receptacle 210. Retainer plate 222 is attached by bolts to ram 230. Annular grooves, such as 244, are machined on the exterior of flow tubes 226, hydraulic tubes 227 and pressure tubes 228, retainer plate 222 being split to facilitate mounting around these tubes at annular grooves 244. Thus, the tubes 226, 227 and 228, ram 230, pressure ring 233, and retainer plate 222 are all fixed for movement together. Ram 230 has a flange lip 245 and a frustoconical inner flange surface 246 in which the seal ring 231 is placed.

Latch key 224 comprises a shank portion 250, an inwardly projecting lip portion 251, an inwardly projecting foot portion 252, a outwardly projecting heel portion 253, and an outer groove 254. Latch keys 224 are held in position by latch cylinder 225, ram 230, pressure ring 233, and sliding latch ring 255. Ring 255 is spring loaded by compression coil springs 255a, preventing latches 224 from prematurely moving around the outer end of ram 230. Springs 255a are mounted in sockets 2306 drilled in face 230a of ram 230, and over pins 255b attached to ring 255.

For running and installing connector 33, its components are first positioned as shown in FIG. 15A. In this position all tubes 226, 227 and 228 lie within the face to face dimension between the flange of hubs 31 and 32, preventing interference when lowering connector 33. Once the connector has been lowered into its resting position on yokes 61 in the support cradle, pressure is applied through center nipple 206 and conduit 218 (FIG. 14) of receptacle 210 into area 260. This pressure forces latch cylinder 225, ram 230, pressure ring 233, latches 224, and tubes 226, 227 and 228 outwardly first to the position shown in FIG. 15B. At this point flange lip 245 of ram 230 and locking flange 255 of hub 32 are abutting one another, seal ring 231 is compressed for sealing and flow tubes 226 and hydraulic tubes 227 have sealingly engaged hub 32 (See FIG. 7 also).

Since ram 230 can move outwardly no further, only latch cylinder 225 and latches 224 will continue to react to pressure within area 260. They will continue to move outwardly, compressing springs 255a, until latch lip 251 falls behind locking flange 98, as shown in FIG. 15C, where latch keys 224 will become stationary since latch foot 252 and latch ring 255 are abutting the back of flange lip 245. Continued pressure will move latch cylinder 225 further outwardly, lip 243 disengaging groove 254 and engaging the inclined surface 260 on the back of lip portion 251. This finally locked position is shown in FIG. 15C. The angles of the inclined surfaces of lip 243 are self-locking, so that pressure may be relieved from area 260 without fear of disengaging latch keys 224.

As will be noticed from FIG. 14 pressure tubes 228 are shorter than tubes 226 and 227. Due to their shorter lengths, pressure tubes 228 do not engage hubs 31 and 32. On full engagement of connector 33 tubes 228 terminate in the area around tubes 226 and 227 encased by seal ring 231. As was previously described, one tube 228 at each end of connector 33 communicates with an outer hole 213 in the rib portion 211 of a receptacle 210. The other set of pressure tubes 228 may be used for return of test fluids or to allow circulation around ring seal 231 to displace salt water which may be present.

To release connector 33 from engagement with hubs 31 and 32, pressure is applied in area 265, through a port (not shown) in cylinder 200. This forces latch cylinder 225, ram 230, latch keys 224, tubes 226, 227, and 228 etc. eventually back to the fully disengaged position shown in FIG. 15A. To fully understand the construction and function of tool 320 and neck 203 (FIG. 13) reference also is now made to FIG. 16. This drawing shows tool 320, running and pulling neck 203, flange 202 on the running sleeve 201, connector cylinder 200, and connector nipple receptacle 210.

Neck 203 has a flange portion 301 which is attached to flange 202 by bolts 302. A tubular prong portion 303 extends upwardly from flange 301. The upper end of prong 303 is provided with frustoconical surface 304. Four V-bottom grooves 305 are circumferentially cut on the interior of prong port end, Drilled longitudinally through the walls of neck 203 are four holes 306, only two of which can be seen in the drawing, each one
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communicating through ports 307 with a different groove 305. Three of holes 306 connect with conduits 26 which sealingly engage holes 213 in receptacle 210 for supplying engaging pressure and test fluid to connector 33 as previously described with reference to Figs. 13 and 14. The fourth hole 306 communicates with port 307 which may in turn be connected by a hydraulic line (not shown) to a port (not shown) in cylinder 200 to supply pressure in area 265 (FIG. 15C) for disengagement of connector 33.

The interior of prong 303 slidingly receives a groove protection cylinder 308 the lower interior of which accommodates a spring 309. An upper annular shoulder 310 is provided with O-ring 311. The length of groove protector 308 is such that when tool 320 is removed, cylinder 308, being spring biased, will cause O-ring 311 to be placed above the uppermost V-groove 305 in prong 303. This will seal the V-grooves 305 against sea water and debris which might plug up the ports. A lower annular shoulder 312 and half dog set screw 313 limit the upward movement of cylinder 308 and prevent it from being lost. A vent hole 308a allows free movement of cylinder 308 by preventing pressure build-up.

Tool 320 has a generally cylindrical body and is provided with connection means such as internal threads 321 for connection to union 300. (See FIG. 13). At its lower end, tool 320 has a smaller diameter prong portion 322. A downwardly facing annular shoulder 323 joins prong 322 to the body of tool 320. External threads are machined at 324 to receive cylindrical sleeve 325. The lower end of sleeve 325 has a frustoconical surface 326. The internal diameter of sleeve 325 is slightly larger than the external diameter of neck prong 303. Looking also at FIG. 17 sleeve 325 has a J-slot 327 which opens at its lower end to receive a pin 328 which projects outwardly and is affixed to neck prong 303. To engage tool 320 and running and pulling neck 303, J-slot 327 and pin 328 must be aligned as the sleeve 325 of tool 320 is lowered around prong 303. Frustoconical surfaces 304 and 326 aid in concentric alignment. When the upper surface 329 of J-slot 327 contacts pin 328 tool 320 may be rotated until pin 328 engages the closed end 330 of J-slot 327. Naturally there is a limited amount of axial freedom at this point between running neck 303 and tool 320. When the tool 320 is pushed all the way down onto neck 303 it is engaged as shown in FIG. 16. However, when it moves up such that pin 328 is in the bottom of slot 330 the pairs of O-rings 331a on prong 322 seal off grooves 305 so that the handling lines do not fill up with sea water.

Tool prong 322 is provided with circumferential V-grooves 331 which in the fully engaged position mate with the internal V-grooves 305 of neck prong 303. Each one of V-grooves 331 is connected by a port 332 to a separate vertical passage 333 drilled in prong 322. These passages 333 in turn are connected by internal ports 334 to external outlets 335 around the exterior of tool 320. These outlets may in turn be fitted with hydraulic hoses (not shown) which are run to the surface to a pressure source at the working boat or platform.

From the description of tool 320, neck 203, and guide frame 100, it can readily be understood that only connector 33 be lowered into engagement with hubs 31 and 32, but it may also be disengaged and returned to the surface.

In summary, with reference to FIG. 1, it has been shown how underwater flowlines 35 may be remotely connected to flow loops 25 of an underwater production tree 10. The construction of a preferred embodiment of flowline connection means comprising support cradle 30, tree hub 31, flowline hub 32, and connector 33 has been explained. A method of installing the flowline connection means has been described. A unique method of handling the installation of flowlines 35 has also been disclosed. As can now be understood from the disclosure, a remote flowline connector may be installed or removed independently of production tree and flowline installation.

Many other variations and uses of the described methods and constructions may be made by one skilled in the art without departing from the spirit of the invention. It is, therefore, intended that the invention be limited only by the scope of the claims which follow.

1. A method of connecting an underwater flowline to a tree assembly positioned in a wellhead near the floor of a body of water, said tree assembly having a flow connection thereon, said method comprising the steps of:

   independently of said tree assembly, guiding connector means through said body of water into a space between one end of said flowline and said flow connection, said one end of said flowline and said flow connection being in coaxial alignment and remotely causing said connector means to engage said flowline and said flow connection for fluidtight flow communication therebetween without disturbing the position of said flowline and said flow connection.

2. The method of claim 1 in which said tree assembly is remotely guided through said body of water and positioned in said wellhead independently of said flowline.

3. The method of claim 1 in which said flowline is guided through said body of water independently of said tree assembly and positioned for nonengaging alignment with said flow connection independently of said tree assembly.

4. A method of connecting an underwater production wellhead positioned near the floor of a body of water to an underwater production flowline comprising, providing a first flow connection means on said production wellhead, providing a second flow connection means on said underwater production flowline in coaxial alignment with said first flow connection means, remotely guiding from above the surface of said body of water, flowline connector means down through said body of water into close proximity with said first and second flow connection means, and remotely engaging said first and second flow connection means with said flowline connector means in fluidtight flow communication therebetween without disturbing the position of said first and second flow connection means.

5. The method of claim 4 in which said flowline connector means is guided down through said body of water along a guide connection established between said wellhead and the space above the surface of said body of water.

6. The method of claim 4 in which said engagement of said first and said second flow connection means is
accomplished through telescopic expansion of a portion of said connector means.

7. A method of installing production equipment at an underwater wellhead positioned near the ocean floor, said method comprising,
guiding a production tree assembly down through a body of water into register with an underwater wellhead, said tree having a fluid flowline connection thereon,
seating said production tree assembly on and securing it to said underwater wellhead,
remotely guiding, from above the surface of the water, the end of an underwater production flow-line down through said body of water and securing said end near to said underwater wellhead in coaxial alignment with the end of said fluid flowline connection,
remotely guiding, from above the surface of the water, flowline connector means down through said body of water into close proximity with said fluid flowline connection and said end of an underwater production flowline, and
remotely causing said connector means to telescopically engage said fluid flowline connection and said end of an underwater flowline without disturbing the position of either and providing fluidtight flow communication therebetween.

8. A method of installing production equipment at an underwater wellhead positioned near the ocean floor, said method comprising,
establishing a guide connection between said wellhead and the space above the surface of a body of water along which equipment may be guided to said wellhead,
guiding a production tree assembly down through said body of water along said guide connection into register with said wellhead, said production tree having a fluid flowline connection extending therefrom,
seating said production tree assembly on and securing it to said underwater wellhead,
guiding the end of an underwater production flowline along said guide connection and securing it in close proximity with and in coaxial alignment with said fluid flowline connection,
guiding flowline connector means along said guide connection into close proximity with said fluid flowline connection and said end of an underwater production flowline, and
through remote means, engaging said flowline connection and said end of an underwater production flowline with said connector for fluidtight flow communication therebetween without disturbing the position of said flowline connection or said end of an underwater production flowline.

9. The method of claim 8 in which said engagement of said flowline connection and said production flowline end is accomplished through telescopic expansion of said connector means.

10. A method of installing an underwater flowline for connection to an underwater production wellhead positioned near the floor of a body of water comprising,
establishing a guide connection between said wellhead and the space above the surface of said body of water,
affixing, above the surface of said body of water, connection means to the end of a flowline,
guiding said flowline and said connection means down through said body of water along said guide connection into register with support means fixed at said wellhead, said support means acting as a fulcrum on which a portion of said connection means comes to rest,
applying a downward force to the end of said connection means to cause it to pivot on said fulcrum into fixed engagement with said support means,
guiding a flowline connector down through said body of water along said guide connection into register with said connection means and flow exit means extending from said underwater production wellhead, and
remotely engaging said connection means and said flow exit means with said flowline connector for fluidtight flow communication therebetween and
without altering the relative positions of said connection means, and said flow exit means.

11. The method of claim 10 wherein said downward force is applied through a string of pipe other than said flowline passing from above the surface of said body of water downwardly to said connection means.

12. The method of claim 10 wherein said guiding and said engagement of said connection means is accomplished through remotely operable means, said remotely operable means being remotely disengagable and reengageable with said connection means for subsequent removal thereof.

13. The method of claim 10 wherein sections of said flowline are coupled together by flexible means to reduce the magnitude of said downward force applied to the end of said connection means.

14. The method of claim 13 in which said flexible means comprises ball and socket joint means, said ball means and socket means being non-axially rotatable with respect to each other.

15. A method of removing production equipment from an underwater well which includes a production tree assembly with a fluid flowline connection thereon, an underwater production flowline, and flowline connector means providing fluidtight flow communication between said fluid flowline connection and one end of said production flowline which are in coaxial alignment, said method comprising the steps of,
remotely disengaging said connector means from said fluid flowline connection and said production flowline without disturbing the position of either, and independently of said tree assembly and said flowline, raising said connector means to the space above a body of water.

16. The method of claim 15 and the additional steps of,
detaching said production tree assembly from said underwater well, and independently of said flowline, raising said production tree assembly to the space above said body of water.

17. The method of claim 15 and the additional step of,
independently of said production tree assembly, raising said flowline to the space above said body of water for replacement, removal, or repair thereof.

18. The method of claim 15 and the additional steps of,
remotely guiding said connector means back down through said body of water into the space vacated by said connector means on its removal, and reengaging said flowline connection and said production flowline with said connector means in fluidtight flow communication therebetween and with disturbing the position of either.

19. Apparatus for remotely connecting the ends of a pair of conduits submerged within a body of water for fluidtight flow communication therebetween, said apparatus comprising
first connection means connected to the end of one of said conduits,
second connection means connected to the end of the other of said conduits and in fixed coaxial spaced relationship with said first connection means, and
connector means adapted to be lowered through said body of water at the ends of said first and second connection means and in juxtapositional relationship therewith, said connector means comprising engagement means adapted for remote operation to engage said first and second connection means for fluidtight flow communication therebetween without disturbing said fixed spaced relationship.

20. The apparatus of claim 19, and guide means in fixed relationship with said first and second connection means engageable with said connector means to guide said connector means from above said body of water to said juxtapositional relationship with said connection means.

21. The apparatus of claim 19 in which a portion of said engagement means is telescopically extendable to engage said connection means in said fluidtight flow communication therewith.

22. The apparatus of claim 19 and a remote power source communicable with said connector means for remote operation thereof.

23. Apparatus for remotely coupling the ends of a pair of conduits submerged in a body of water, said apparatus comprising,
guide means stationarily fixed near the floor of said body of water and extending upwardly to the space above said body of water,
first coupling means secured to the end of one of said conduits,
second coupling means secured to the end of the other of said conduits and in coaxial alignment with said first coupling means,
connector means engageable with said guide means and adapted to be lowered from above said body of water to a point in juxtaposition with said first and second coupling means, said connector means comprising slidable engagement means, remotely operable to engage said first and second coupling means for fluidtight flow communication therebetween without disturbing the relative positions of said first and second coupling means.

24. The apparatus of claim 23 in which said connector means comprises flow passage means slidably received within a portion of said connector means for extension to sealingly engage other passage means in said first and second coupling means so that fluidtight flow communication exists between said pair of conduits.

25. The apparatus of claim 23 in which said engagement means comprises latch means adapted to engage said first and second coupling means, said latch means lying within the minimum distance between said coupling means before said engagement and being extendable on said engagement to contact a portion of said first and second coupling means in disengangeable engagement therewith.

26. The apparatus of claim 23 and remote power means connected to said connector to move said engagement means into said contact with said first and second coupling means.

27. Apparatus for remotely connecting underwater production equipment to a wellhead submerged in a body of water, said apparatus comprising,
guide means affixed to said wellhead and extending upwardly through said body of water to a working position above said body of water, production tree means engageable with said guide means and adapted to be guided thereby into register with said wellhead, said tree means comprising flow exit means, connection means affixed to said tree means and said wellhead for remote connection thereof in fluid flow relationship therewith,
first coupling means affixed to said flow exit means, second coupling means attached to one end of an underwater flowline, said second coupling means being engageable with said guide means and adapted to be lowered into stationary juxtapositional relationship with said first coupling means with a space therebetween, flowline connector means engageable with said guide means and adapted to be guided thereby into said space independently of said flowline, said connector means being remotely operable for engaging said first and second coupling means in fluidtight flow communication therebetween and without disturbing the stationary juxtapositional relationship between said first and second coupling means.

28. The apparatus of claim 27 in which said first and second coupling means comprise hub-like means with flow passages therethrough and flange means on the adjacent ends of each coupling means.

29. The apparatus of claim 28 in which said connector means comprises passage means and latch means slidably mounted in a portion of said connector means for engagement with said coupling flange means.

30. Apparatus for connecting an underwater flowline to a wellhead with flow exit means submerged in a body of water, said apparatus comprising
support means affixed near the floor of said body of water in fixed relationship with said wellhead, first coupling means connected in flow relationship with said flow exit means and supported by said support means second coupling means connected to one end of said underwater flowline in flow relationship therewith, said second coupling means and said flowline end being adapted for lowering through said body of water to a position whereby at least one end of said second coupling means contacts a portion of said support means at a contact point thereon, said second coupling means and said flowline end being adapted to pivot about said contact point into coaxial alignment with said first coupling means leaving a space therebetween, and coupling connector means adapted to be remotely lowered through said body of water independently
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of said first and second coupling means into said space to provide fluidtight flow communication therebetween.

31. The apparatus of claim 30 in which said coupling connector comprises flow means telescopically mounted therein, said flow means being adapted to extendably engage in sealing flow relationship flow passages in said first and second coupling means.

32. The apparatus of claim 30 in which said coupling connector means comprises engagement means slidingly retained in a portion of said connector means, said engagement means being adapted for remote operation to engage a portion of said first and second coupling means.

33. The apparatus of claim 32 in which said engagement means comprises cylinder and piston means, pressure operable to cooperate with said engagement means for said remote operation to engage said first and second coupling means.

34. The apparatus of claim 31 in which said coupling connector means comprises pressure operable cylinder and piston means cooperating with said flow means to extendably engage said flow passages in said first and second coupling means.

35. Apparatus for connecting an underwater flowline to flow exit means in a wellhead submerged in a body of water, said apparatus comprising:

- first coupling means connected to said flow exit means stationarily fixed near said wellhead,
- second coupling means connected to the end of said flowline, said second coupling means being adapted for lowering through said body of water into a stationary position co-axially aligned with said first coupling means with a space therebetween,
- coupling connector means adapted to be remotely lowered through said body of water independently of said first and second coupling means into said space, said connector means having flow passages therethrough and engagement means adapted for remote operation from a retracted position to a position engaging said first and second coupling means for fluidtight flow communication therebetween.

36. The apparatus of claim 35 in which said flowline comprises pipe sections connected by flexible joints to reduce the resistance to said co-axial alignment of said first and second coupling means.

37. The apparatus of claim 36 in which said flexible joints are adapted to prevent axial rotation of adjacent pipe sections relative to each other.

38. The apparatus of claim 37 in which said flexible joints comprise limiting means to limit co-axial disalignment of adjacent said pipe sections to a degree small enough to permit passage of in-line flow tools.

39. The apparatus of claim 37 in which said joint comprises ball and socket means.

40. The apparatus of claim 39 in which said ball and socket means comprise cooperating key and key slot means to prevent said relative axial rotation of said adjacent joints.

41. Apparatus for remotely connecting an underwater wellhead to an underwater flowline in a body of water, said apparatus comprising:

- flow exit means connected to said wellhead,
- first coupling means connected to said flow exit means,
- second coupling means connected to one end of said flowline, said coupling means and end of said flowline being adapted for lowering through said body of water into a predetermined position relative to said first coupling means with a space therebetween,
- connector means adapted to be lowered through said body of water independently of said first and second coupling means into said space between said second coupling means, said connector means having flow passage means therethrough and engagement means thereon, said engagement means being remotely operable to engage a portion of each of said coupling means for fluidtight flow communication therebetween, without altering said space between said coupling means.

42. The apparatus of claim 41 in which said engagement means is adapted for remote disengagement from said coupling means, without disturbing their positions, and for removal from said body of water independent of said first and second coupling means.

43. The apparatus of claim 41 in which said connector means comprises cylinder means and piston means reciprocally mounted therein, said cylinder means being connected to a pressure source to translate operating movement of said engagement means through said piston means.

44. The apparatus of claim 43 in which said second coupling means and said end of flowline are adapted for remote removal from said body of water independent of said first coupling means.

45. Apparatus for remotely connecting an underwater flowline to flow exit means in a wellhead submerged in a body of water, said apparatus comprising:

- first coupling means connected to said flow exit means in a stationary position, said second coupling means being adapted for lowering through said body of water into a stationary position co-axially aligned with said first coupling means, second coupling means being adapted for lowering through said body of water to a position of support in close proximity with said first coupling means,
- pivot means affixed at said support position, said second coupling means and said end of said flowline being adapted to pivot about said pivot means into coaxial alignment with said first coupling means, and
- connector means independently lowerable from above said body of water to a position between the ends of said first and second coupling means, said connector means being remotely operable to engage the ends of said first and second coupling means for fluidtight flow communication therebetween without altering the said stationary position of said first coupling means.

46. The apparatus of claim 45 and force transmitting means engageable with said second coupling means and said end of said flowline for said pivoting thereof.

47. The apparatus of claim 45 in which said flowline comprises pipe sections connected by flexible joints to reduce the resistance of said co-axial alignment of said second coupling means.

48. The apparatus of claim 49 in which said flexible joints comprise ball and socket means adapted to limit co-axial non-alignment of adjacent said pipe sections to
an amount small enough to allow passage of in-line flow tools.

49. The apparatus of claim 47 in which said flexible joints are adapted to prevent axial rotation of adjacent pipe sections relative to each other.

50. The apparatus of claim 49 in which said flexible joints comprise ball and socket means, said ball and socket means being provided with key and key slot means for said prevention of relative axial rotation of said adjacent pipe sections.

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