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(54) Subsea electrical connector and method.

(57) A remotely operable electrical connector (10) comprising a movable extension arm (72) with an electrical plug (12) thereon in a housing (60) located on one member, such as a control module (14) and which is hydraulically axially movable toward an electrical receptacle (20) located on a second member, such as the production tree (22). The connection of the plug and receptacle is a two step operation. The first step is initial engagement of the plug - (12) in the receptacle (22) at which time the end of the plug (12) and the base (204) of the receptacle - (22) are purged to clean all the electrical contact surfaces. Thereafter, the extension arm (72) is moved to position the plug (12) in its final connected position within the receptacle (20). A spring (122) biases the plug (12) toward the final face-to-face position in the receptacle wall at all times to ensure good electrical contact and sealing against seawater intrusion. The plug (12) may also be hydraulically urged toward the final face-to-face contact. The extension arm (72) has a gimbal (132) allowing relative universal movement between the extension arm (72) and the housing (60) and second alignment means - (92, 94 and 100) between the extension arm (72) and the plug (12), both of which operate to compensate for any misalignment as the plug (12) engages a receptacle (22).

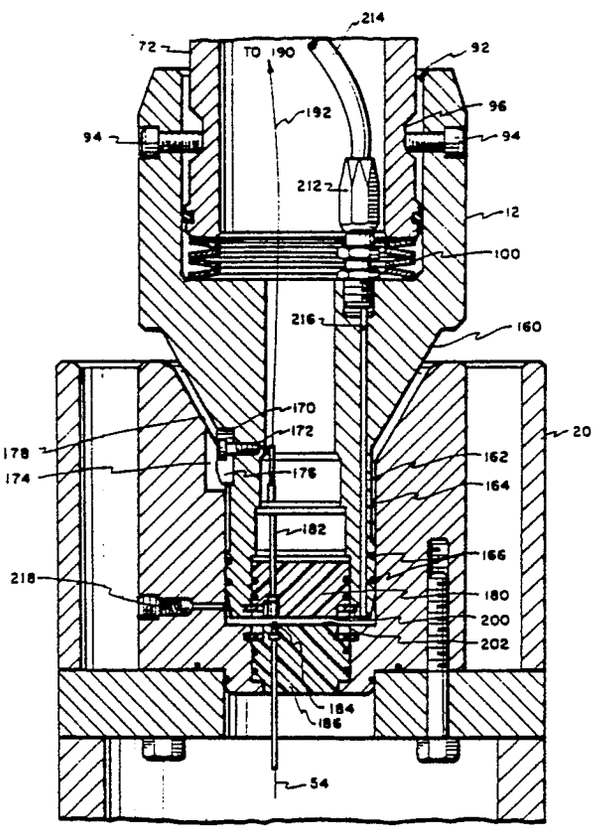

Fig. 5.

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SUBSEA ELECTRICAL CONNECTOR AND METHOD

BACKGROUND OF THE INVENTION

This invention relates to equipment for producing from a subsea oil or gas well and is particularly directed to an improvement in the means by which conductive electrical connections are made between the various pieces of equipment.

The pieces of equipment used to produce from a subsea well conventionally include a completion tree which is connected to the wellhead located at or near the mudline, a control module containing various actuators for controlling valves located on the completion tree and within the well itself, and a tree cap having a plurality of hydraulic control lines for connecting the various actuators within the control module, the tree, and in the well itself to a surface vessel at the water level.

When producing oil or gas from any wellhead, it is important to obtain data regarding the pressure and temperature of oil reserves as they migrate up the well. This data provides the rig operator with vital information with regard to the reservoir, oil basin, sediment layer geology, expected life of the producing well, gas and corrosives entering the well, etc. Sometimes additional electrical data is required such as the position of the gates in the valves located on the subsea production tree.

This data gathering is usually accomplished electrically and normally requires a remotely operated electrical connection between the subsea production tree and a separately retrievable control module.

Occasionally, an operator is faced with accomplishing the connection of the control module to the subsea production tree and to make electrical connection in deep water without the aid of wire rope guide lines to run and retrieve the control module. To do this, a large diameter re-entry funnel is located at the top of the tree. The funnel provides for a large capture zone to land the control module and guide the same onto the mating mandrel of the tree. However, this large diameter funnel (one half of the connector) then requires the electrical connector to stroke several feet in order to mate with the receptacle (the other half of the connector). This causes a problem as it is difficult to achieve the proper alignment of the two electrical connector mating halves.

Thus, the following factors combined compound to make the remote interface of the electrical connector a problem:

1. The electrical connector half (plug) on the module has to be located a long distance from its mating receptacle on the tree. This is to allow the connector halves to retract clear of the re-entry funnel during running and orienting of the control module onto the tree,

2. The movement of each of the connector halves induced by the welding of the structural steel framework on which the connector halves are mounted cannot be predetermined,

3. The orientation and alignment required to engage an electrical pin type connector is very precise and care must be taken to prevent damage to the pins while, at the same time, providing for a properly conducting interface,

4. The primary seal of environment-to-pin is provided by a face-to-face seal across the flat surfaces that house the pin on the plug side and the socket on the receptacle side. These two surfaces must meet flat and parallel with each other in almost perfect position. Additionally, a constant preload must be maintained on the connector halves in order that the primary seal continues to perform its function,

5. A tolerance build-up between all of the components on the control module and those on the tree, the electrical plug connector and mating receptacle is great enough to require at least one free floating member.

6. The plug half of the connector must remain retracted during running in the event of a hydraulic fluid power loss so as not to damage the plug during funnel entry, and

7. The interface between the connector halves must remain connected, preloaded and sealed in the event of a hydraulic fluid power loss so as to prevent costly electrical shorting.

SUMMARY OF THE INVENTION

The remotely operable electrical connector which accomplishes the foregoing, comprises a movable extension arm with an electrical plug thereon in a housing located on one member, such as a control module, and which is hydraulically axially movable toward an electrical receptacle located on a second member, such as the production tree. The connection of the plug and receptacle is a two step operation. The first step is initial engagement of the plug in the receptacle at which time the end of the plug and the receptacle are purged to clean all the electrical contact surfaces. Thereafter, the extension arm is moved to position the plug in its final connected position within the receptacle as the second step. A spring biases the plug toward the final face-to-face position in the receptacle wall at all times to ensure good elec-

trical contact and sealing against seawater intrusion. The plug may also be hydraulically urged toward the final face-to-face contact. The extension arm has a gimbal allowing relative universal movement between the extension arm and the housing and second alignment means between the extension arm and the electrical plug, both of which operate to compensate for any misalignment as the plug engages a receptacle.

The plug has a series of three mechanical springs which enable it to remain either in the retracted position or in the engaged, preloaded, sealed position, even in the event of a hydraulic fluid power failure.

The plug is retractable back to the housing at any time and capable of reconnection utilizing the same procedure.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic illustration of a subsea production tree having landed on a permanent guide base with a control module positioned above the tree and about to be connected thereto, and also shows an electrical receptacle located on the production tree and an electrical plug on the control module,

Figure 2 is a top view of the electrical connection,

Figure 3 is a quarter view in elevation, taken along line 3-3 of Figure 2 and showing the plug-socket relationship,

Figure 4 is a cross-sectional view taken along line 4-4 of Figure 3,

Figure 5 is a cross-sectional view, enlarged over those of Figure 3, showing the plug and socket initially engaged, and

Figure 6 is an elevational view like that of Figure 3 but showing the final engagement of the plug and socket.

DETAILED DESCRIPTION

Figure 1 is a schematic illustration of subsea equipment in which the remotely controllable electrical connection comprising this invention is used. This invention is identified in its entirety as 10 and as shown comprises an electrical plug 12 located on a control module 14 together with means 16 for lowering and guiding this plug into a receptacle 20 located on a completion tree 22. The plug 12 and receptacle 20 are the above referred to mating connector halves.

Before the completion tree 22 was positioned as shown, a temporary guide base 24 was positioned on the ocean floor (mudline) and used for drilling a well bore. A permanent guide base 26 was positioned on the temporary guide base 24 which also had been lowered from the water surface and connected thereto. Positioned over the guide base 26 is the completion tree 22 which had been lowered from the water surface, oriented by posts 30 on the permanent guide base 26 and on the completion tree 22 and connected to the permanent guide base 26 by a suitable connector, not shown. This completion tree 22 contains suitable valves and valve actuators 32 for controlling the various functions of the completion tree.

Spaced above the completion tree 22 is the control module 14 which will be lowered onto the completion tree 22 and connected by a suitable connector. The control module will be lowered with or without the aid of guidelines. To allow the operator the option of lowering the control module without guidelines, both the completion tree 22 and the control module 14 have a complementary funnel/cone system 36 to also guide the control module 14 with respect to the completion tree 22. The control module 14 has control pods 40 with hydraulic control lines to be connected to hydraulic control lines 42 on the completion tree 22 for controlling the valve actuators 32. These control pods 40 are connected hydraulically to the vessel on the surface of the water by hydraulic control lines 44. Also, electric wiring 50 and hydraulic control lines 52 are shown connected to the plug 12 and electrical wiring 54 is shown connected to the receptacle 20 so that electrical power can be transmitted to and from the plug and receptacle for the purpose above described.

It can be appreciated, even from this schematic illustration, that the alignment and connection with the control module 14 to the completion tree 22, manufacturing tolerances in the structure themselves, the size and shape of the funnel/cone guidance system 36 and other factors require the plug 12 to travel a considerable distance to the receptacle 20, require both to accommodate some misalignment, and require a watertight and good electrical connection to be made therebetween.

The means 16 for accomplishing this connection in this invention will now be described.

Figures 3-6 show the means 16 for stroking and connecting the plug 12 to the receptacle 20 as comprising an elongated tubular member or housing 60 connected in any suitable manner, as by bolts 62, to a mounting plate 64 on the control module 14, and orientated so as to open downwardly toward the receptacle 20 on the completion tree 22. The receptacle 20 is attached by a mounting plate 66 to the completion tree 22 by any

suitable means, such as bolts, through bores 70. Within the housing 60 is a second long tubular member or extension arm 72 with the plug 12 connected thereto and adapted to move axially of the housing 60, i.e., to be stroked toward the receptacle 20 by a hydraulic cylinder 74 pivotally attached at one end of the housing 60 and pivotally attached at the other end to a drive ring 76. The connection of the drive ring 76 to the extension arm 72 will be described in detail later. The housing 60 has an elongated slot 80 on one side of the housing to allow movement of the parts connecting the piston rod of the cylinder 70 to the drive ring 76. Two hydraulic cylinders 74 and slots 80 are shown in Figure 4. There is also a key slot 82 in the housing 60. This key slot acts, among other things, to guide the extension arm which has a key 84 fastened thereto by a bolt. Guides 86 are also provided within the housing 60 for the extension arm 72. When the extension arm is retracted within the housing 60, the housing 60 serves to protect the extension arm and plug 12 during running and retraction of the control module.

As mentioned before, the extension arm 72 is connected to the plug 12 which, as more clearly shown in Figure 5, has a socket 92 to loosely receive this end of the extension arm 72 and is attached thereto by set screws 94 in a peripheral groove 96 on the outside wall of the extension arm. This groove 96 is wider than necessary for connecting the plug 12 to the extension arm and provides a loose connection therebetween to allow the plug 12 to have a slight angular adjustment to align itself with the receptacle 20 on their initial engagement. Within the socket 92 and engaging both the plug 12 and the end of the extension arm, is a plurality of Belleville washers 100 which serve to maintain the plug 12 oriented and in operational engagement with the extension arm, yet at the same time allow for slight angular misalignment between the extension arm and the plug upon engagement of the plug with the receptacle. How the preloading of the Belleville washer assembly aids in producing an effective seal and good electrical contact will be discussed hereinafter.

The other end of the extension arm is capped by an end cap 102 having leg 104 telescoped into and sealed in the inner wall of the extension arm and fixed to the arm by set screws 106. Opposite leg 104, the end cap 102 extends in the direction of the drive ring 76 and has a piston chamber 110 with a reciprocable piston 112. This chamber 110 has two hydraulic control fittings 114 and 116 located on each side of the piston 112 for directing fluid into the chamber to control the movement of the piston. These control fittings are connected by hydraulic control lines 52 (Figure 1) to the surface vessel. These control lines enter the housing 80 through the guide slot 82. The piston 112 has a piston rod 120 extending beyond the cap through a helical spring 122 to be threadably connected at 124 to a thicker rod 126. This thicker rod 126 extends through a bore 128 in the drive ring 76 and is threadably connected by a nut 130 to a hemispherical gimbal member 132 which seats in a complementary hemispherical seat 134 in the ring 76. The bore 128 is oversized with respect to the thicker rod 126 to allow for any misalignment between the thicker rod 126 and the drive ring 76. The spring force (rate) of the helical spring 122 is regulated by the threaded connection 124 between the piston rod 120 which controls the position of the piston rod 120 relative to the thicker rod 126 and a seat ring 140. The piston 112 and its rod 120, responsive to fluid pressure in fitting 116, holds the helical spring 122 in its retracted position until the final positioning of the plug 12 is to be made, as will be described infra.

Thus far described, it can be seen that the extension arm 72 is stroked by the hydraulic cylinder 74 in and out of the housing 60 and that the extension arm 72 has two means for compensating for misalignment, that is, the last described gimbal/sent 132-134 and the set screw groove/Belleville washer arrangement 94, 96-100. This misalignment compensating means makes the plug 12 a free floating member mentioned above.

When the extension arm 72 is retracted within the housing 60, it is held in place by a detent spring 142 in a detent groove 144 in the housing and located near the top thereof. The detent spring 142 is a split-ring located on a reduced portion 146 on the drive ring 76 and held in place by a retaining ring 150 threaded on the drive ring 76 and fastened thereto by bolts (not shown). When the cylinder 74 strokes the extension arm 72 out of the housing 60, the detent spring 142 retracts and moves along with the drive ring 76 to a second detent groove 154 (Figure 6) in the housing 60 where the detent ring 142 again expands and locks the extension arm 72 in a first extended position. This is the first step in the two step operation to connect the plug 12 in the receptacle 20. The force necessary to move the detent ring 142 out of the detent groove 154 exceeds the force of the helical spring operable to move the extension arm 72 to its final position, the second step in the connection, when released by the piston 112 and rod 120.

In this first extended position of the extension arm 72, the plug initially enters the receptacle 20 but is not fully received therein. See Figure 5.

The plug 12 is provided with a downwardly tapered conical midsection 160 which terminates in a stab 162 of lesser diameter than the overall diameter of the plug 12 to enter into a cylindrical counterbore 164 in the receptacle. This tab 162

has circumferentially disposed O-ring seals 166 on its outer diameter which engage the counterbore in sealing relationship. The plug is also provided with an orientation key 170 attached to the plug 12 by a suitable bolt 172. This orientation key engages an alignment slot 174 in the receptacle located at the outboard end of the counterbore. The key is tapered at 176 to cooperate with a taper 178 on the alignment slot to facilitate entry and the plug 12 is capable of rotating so that the orientation key can enter the key slot because of the relationship of the set screws 94 and groove 96 loosely fastening the plug 12 onto the extension arm 72.

The plug 12 is hollow and is provided with a plastic insert 180 which contains suitable electrical conductive pin connectors 182 (one shown) which will engage electrical conductive sockets 184 (one shown) in a complementary plastic insert 186 in the receptacle 20. The shown pin connector 182 is connected back to a fitting 190 in the wall of the extension arm by a line 192. The fitting 190 is connected back to the vessel at the surface by lines 50 (Figure 1) while the box connector 186 is connected subsea by line 54.

In this initial position of the ring, the end wall 200 of the insert 180 and base 202 of insert 186 are not engaged leaving a space so that these walls may be purged (washed) with a dielectric fluid. To do this, the cap 102 at the other end of the extension arm is provided with a conduit 204 connected to a fitting 206 which, in turn is connected to one of the hydraulic lines 52 extending through the key slot 82. The leg 104 of the cap 102 is also provided with a fitting 210 which connects with a fitting 212 on the plug 12 by a purge hose 214. The fitting 21 is connected to a relatively small passage 216 extending axially of the plug 12 and opening at the end wall 200 of the stab. Dielectric fluid is directed through the end cap 104 through the purge hose 214, out the end of the stab, and into the space created by the end wall 200 and the base 202 of the insert 186. This fluid is then flushed out to sea against a one-way spring-actuated purge check valve 218 connecting with this space and located in the connector housing. After purging, and while the extension arm and plug are in this initial extended position, the high pressure at the fitting 116 holding the piston 112 against the bias of the helical spring 122, is vented, allowing the helical spring to expand and urge the plug 12 toward its final position where the stab end wall 200 engages the base 202 of the insert 186, forms a face-to-face seal therewith, and connecting the electrical conductive pin connector 182 to the electrical conductive socket 184.

In practice, the conductive electrical connector, i.e., the inserts 180 and 186, having a quantity of 45 pins/sockets, requires that the mating face-to-face of endwall 200 and base 202 be engaged with an opposing force maintained of approximately 350 pounds. This is to obtain and maintain an effective seal between the pins and environment (seawater).

In order to accomplish this, the Belleville washer assembly 100 must be assembled in a pre-loaded condition such that,

1. The pre-load is greater than the required opposing force of the 350 pounds to achieve the face-to-face seal at 200 and 202.

2. The preload is greater than the 350 pound face-to-face seal by as much as required so that the plug 12 and receptacle 20 in their worst off-set alignments maintain the 350 pound force on the most separated side of the Belleville washers.

In order to achieve a satisfactory connection, the entire preload of the plug 12 to the receptacle 20 must be maintained such that the following applies:

a. When the plug 12 is positioned at its greatest distance from the receptacle 20 due to the tolerance buildups and fabrication movements, as discussed, supra, the helical spring 122 is preloaded to a force which exherts more that the spring preload force of the Belleville washer assembly 100 in their assembled position as described in items 1 and 2 above.

b. When the plug 12 is in its worst offset alignment position from the mating receptacle 20, the preload must be great enough so that the most separated side of the helical spring 122 retains a force as described in item 1 above.

c. The detent spring 142 and its mating grooves 144 and 300 must have enough expanding force such that the force required to move the detent spring out of its groove is greater than the largest force exherted by helical spring 122 in the mated position of the plug 12 and receptacle 20.

It is to be understood that the 350 pound force is used as an example for the 45 pin connection described. The preload forces required evolve from this number. However, it is recognized that a 5 pin connection may require only 50 pounds of opposing force and hence the spring forces would be predetermined as accordingly required.

It should be clear, therefore, that the bias of the helical spring 122 is greater than the bias of the Belleville washer assembly 100 so that the face-to-face seal is maintained, but if additional loading is desired to further ensure maintenance of the face-to-face seal, fluid pressure can be communicated to fitting 116 to urge the piston toward the drive plug 76 where a hydraulic backup plug 220 -

(Figures 3 and 6) will be forced toward the drive ring lifting the gimbal 132 off its seat if necessary. As shown, the back-up ring is threaded onto the thicker rod 124.

Claims

1. A remotely controllable electrical means for electrically connecting subsea equipment together comprising,
a housing on one piece of subsea equipment,
an extension arm initially within said housing,
a plug with electrical conductive pin means and on said extension arm,
a receptacle with electrical conductive socket means on another piece of subsea equipment,
both pieces of subsea equipment being connectable together and aligned so that said extension arm and plug are substantially aligned with said receptacle,
means for moving said extension arm out of said housing and towards said receptacle and into initial engagement therewith so that the end of said plug is within said receptacle but spaced from the base of said receptacle,
means for cleaning the end of said plug and the base of said receptacle, and
means for urging the end of said plug into engagement with the base of said receptacle so that said electrical conductive pin means engage said electrical socket means.

2. The electrical means as claimed in Claim 1 wherein said means for urging said plug end toward said base is operable without movement of said extension arm.

3. The electrical means as claimed in Claim 2 wherein said means for urging said plug end into engagement with said base comprises spring means.

4. The electrical means as claimed in Claim 3 wherein said means includes means between said plug and said extension arm allowing for limited misalignment between said plug and said receptacle upon said initial engagement.

5. The electrical means as claimed in Claim 4 wherein said misalignment means comprises spring means.

6. The electrical means as claimed in Claim 5 wherein said first-mentioned spring means overcomes the bias said second-mentioned spring means.

7. The electrical means as claimed in Claim 6 including a second misalignment means between extension arm and said housing.

8. The electrical means as claimed in Claim 7 wherein said misalignment means comprises a gimbal means.

9. The electrical means as claimed in Claim 8 wherein the means for moving said extension arm out of said housing comprises hydraulic means.

10. The electrical means as claimed in Claim 9 wherein said hydraulic means is capable of withdrawing said extension arm back into said housing.

11. The electrical means as claimed in Claim 10 wherein said first-mentioned spring means is held in its contracted position before said initial engagement by a second hydraulic means under fluid pressure and wherein said spring means is allowed to expend by the venting of said hydraulic means.

12. The electrical means as claimed in Claim 11 wherein said second hydraulic means may also provide further bias to further overcome said second-mentioned spring means.

13. A method of electrically and remotely making electrical connection subsea comprising the steps of
providing a plug with electrical conductive pin means,
providing a receptacle with electrical conductive socket means,
initially engaging said plug and receptacle and providing a space between the end of said plug and the base of said receptacle,cleaning the end of said plug and base of said receptacle, and
connecting said pin means and socket means.

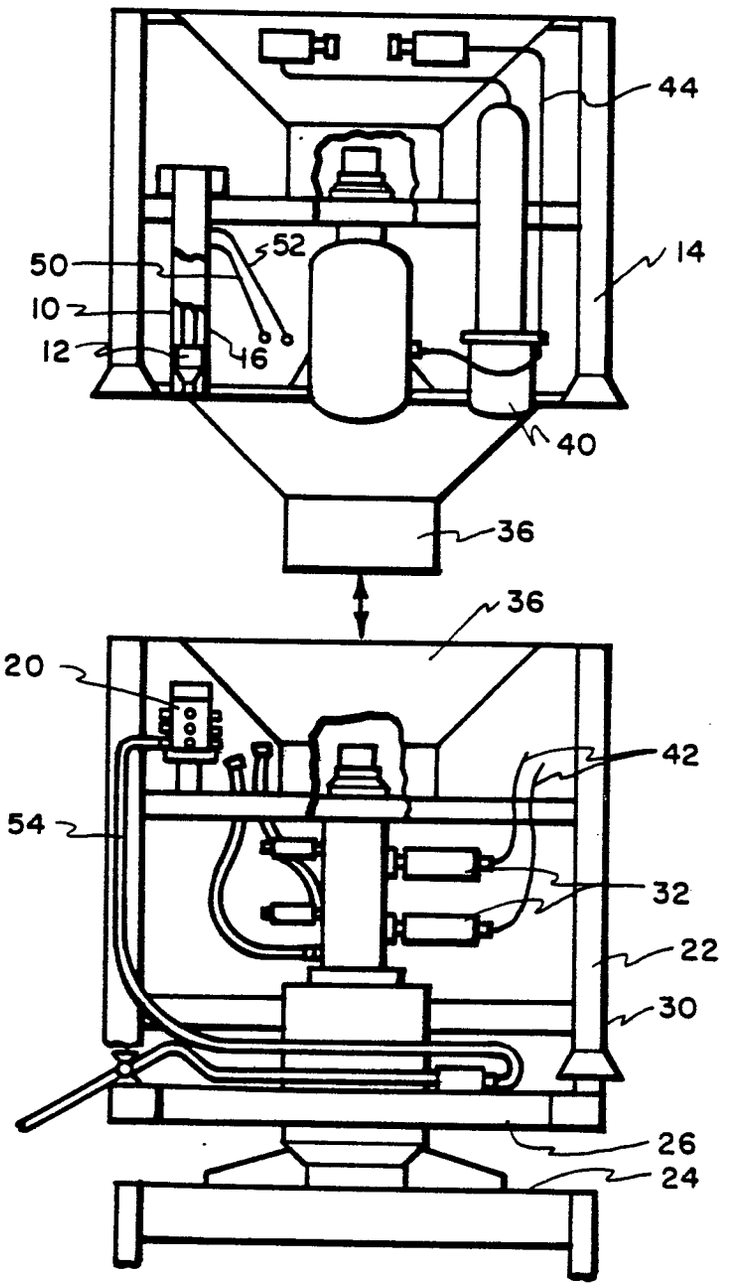


Fig. 1.

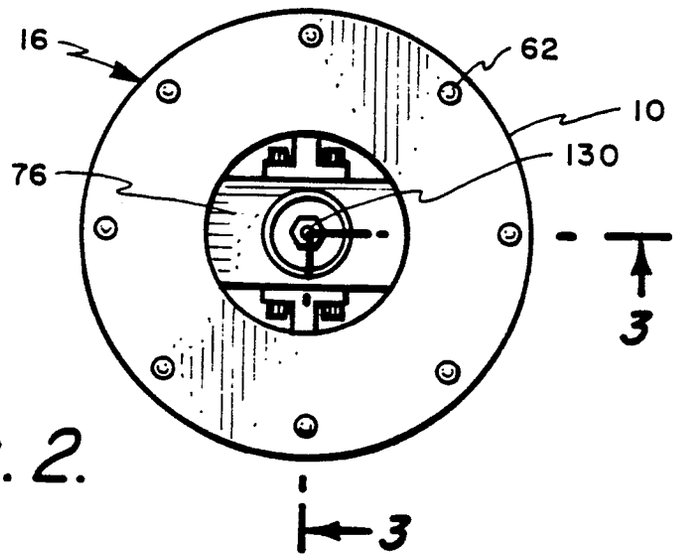
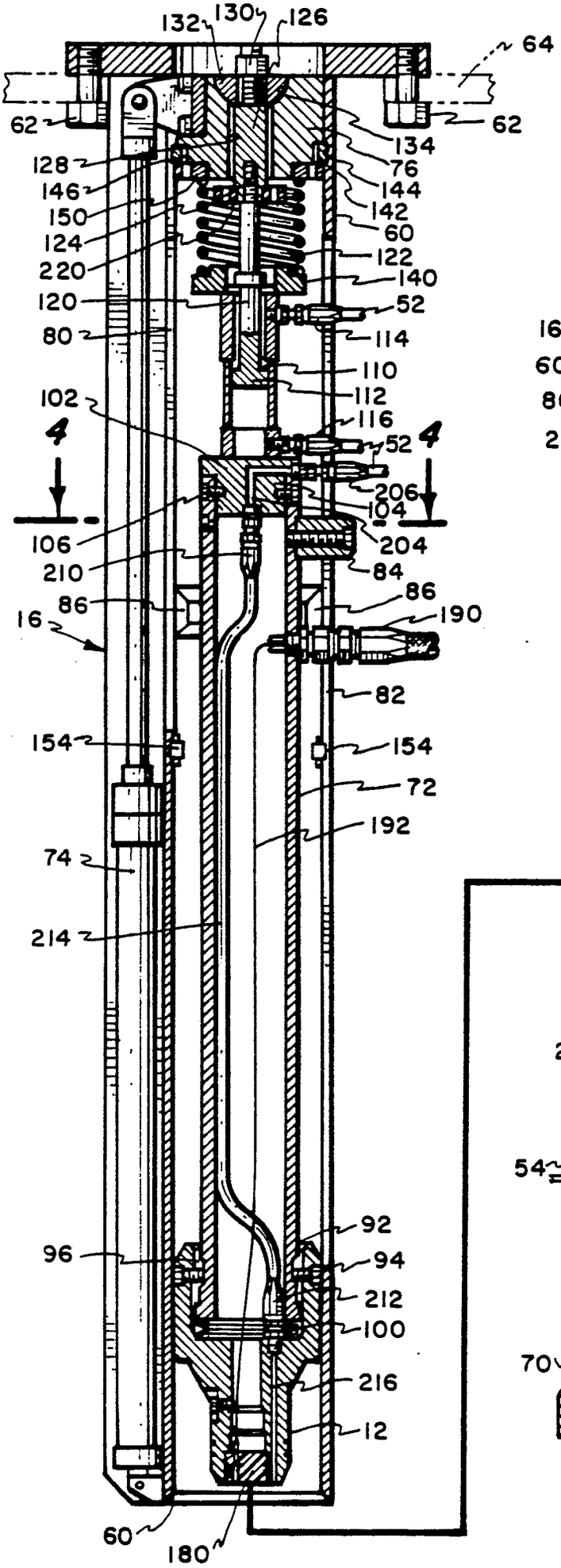


Fig. 2.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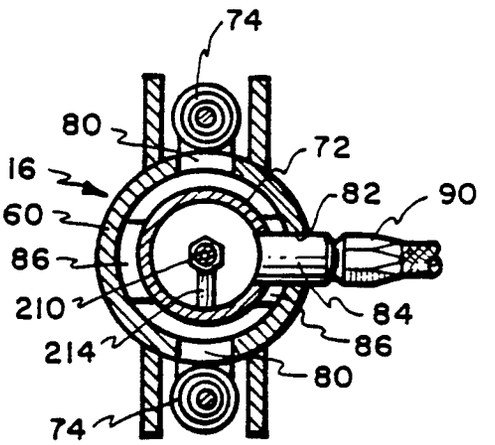
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Fig. 4.

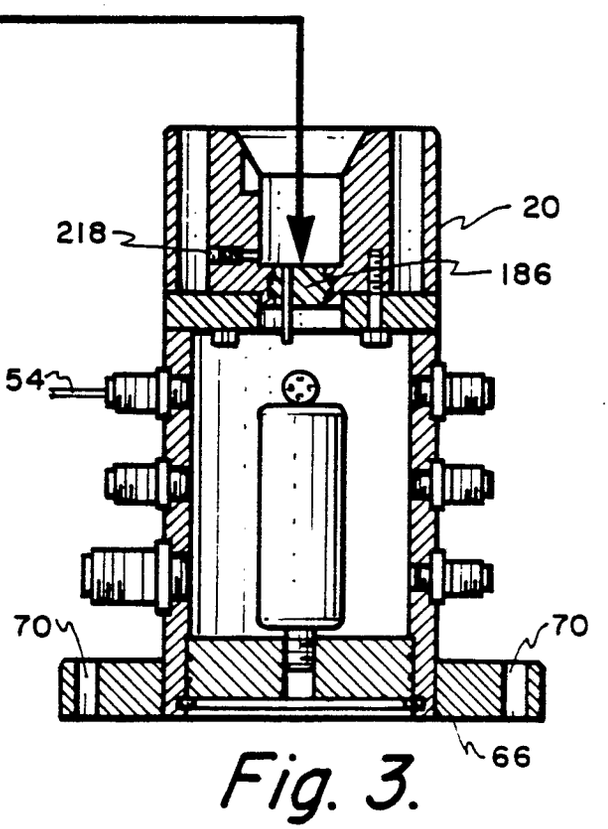
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Fig. 3.

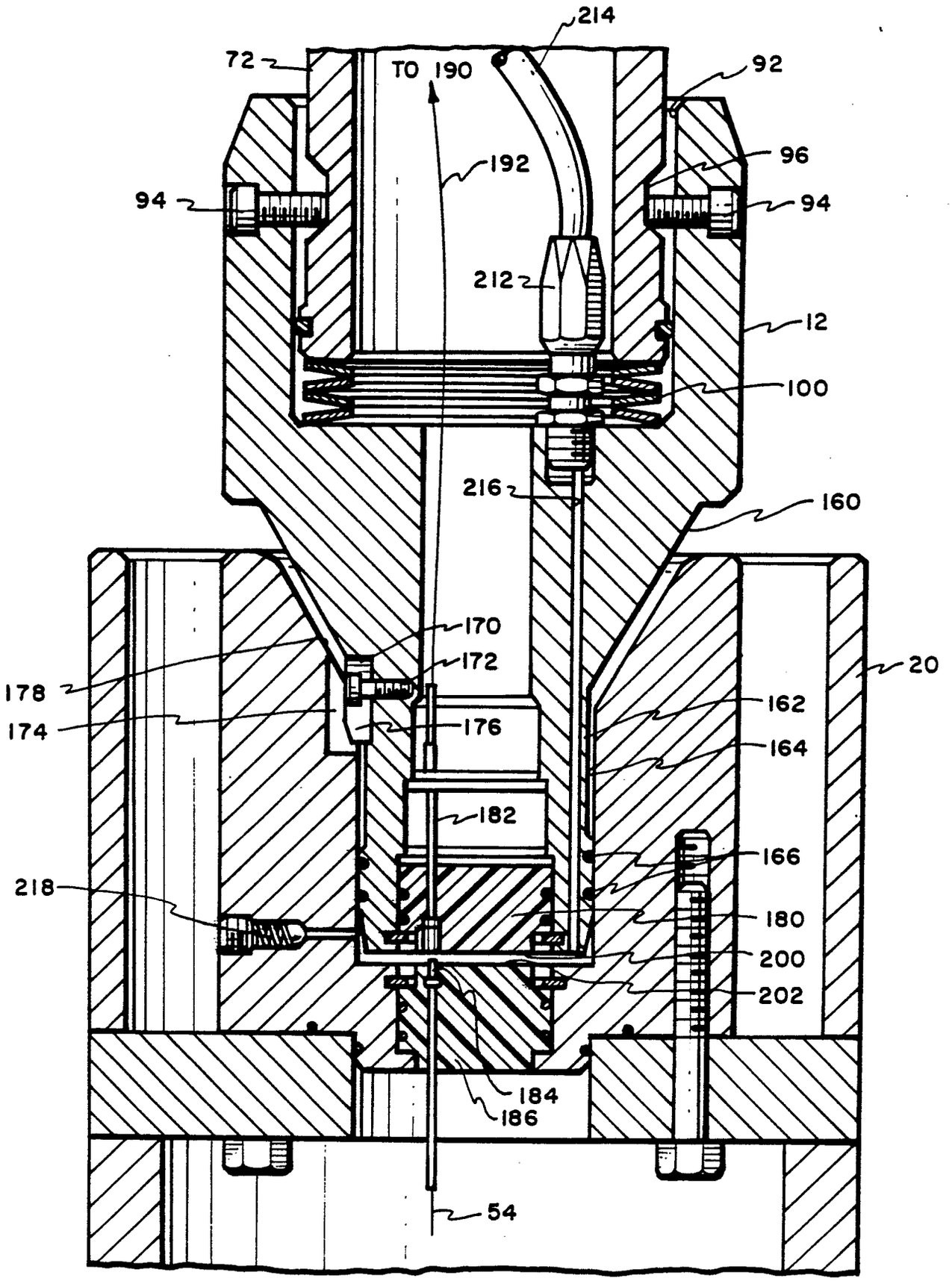
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Fig. 5.

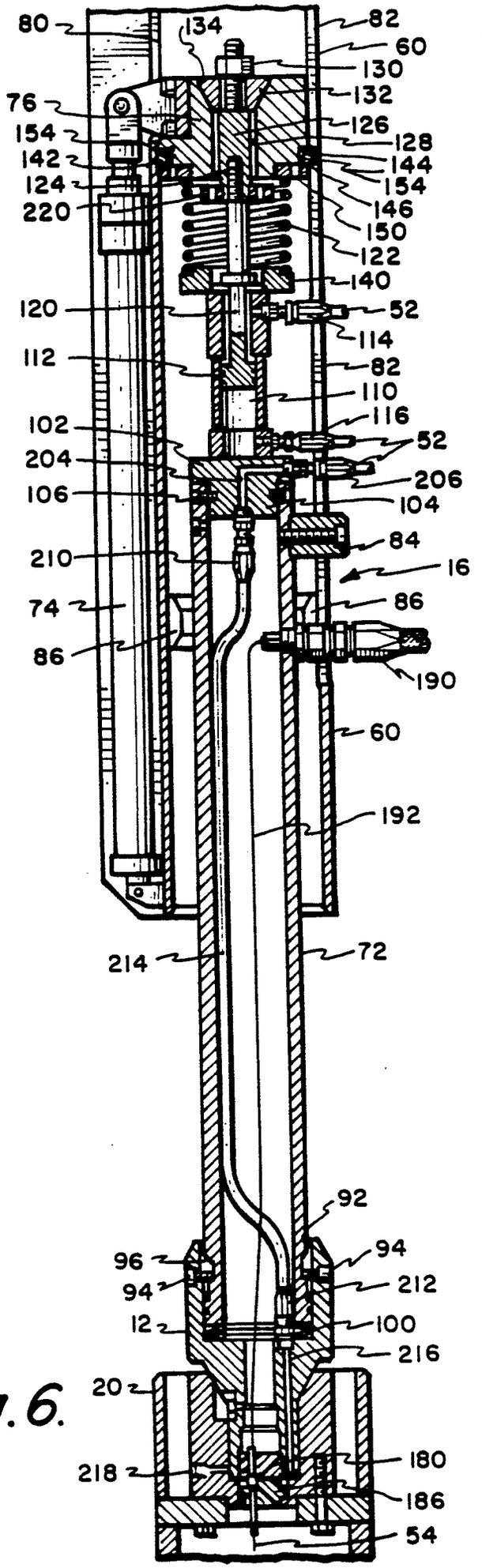
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Fig. 6.