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R. S. HOCH

3,211,223

UNDERWATER WELL COMPLETION

Filed Dec. 26, 1961

6 Sheets-Sheet 1

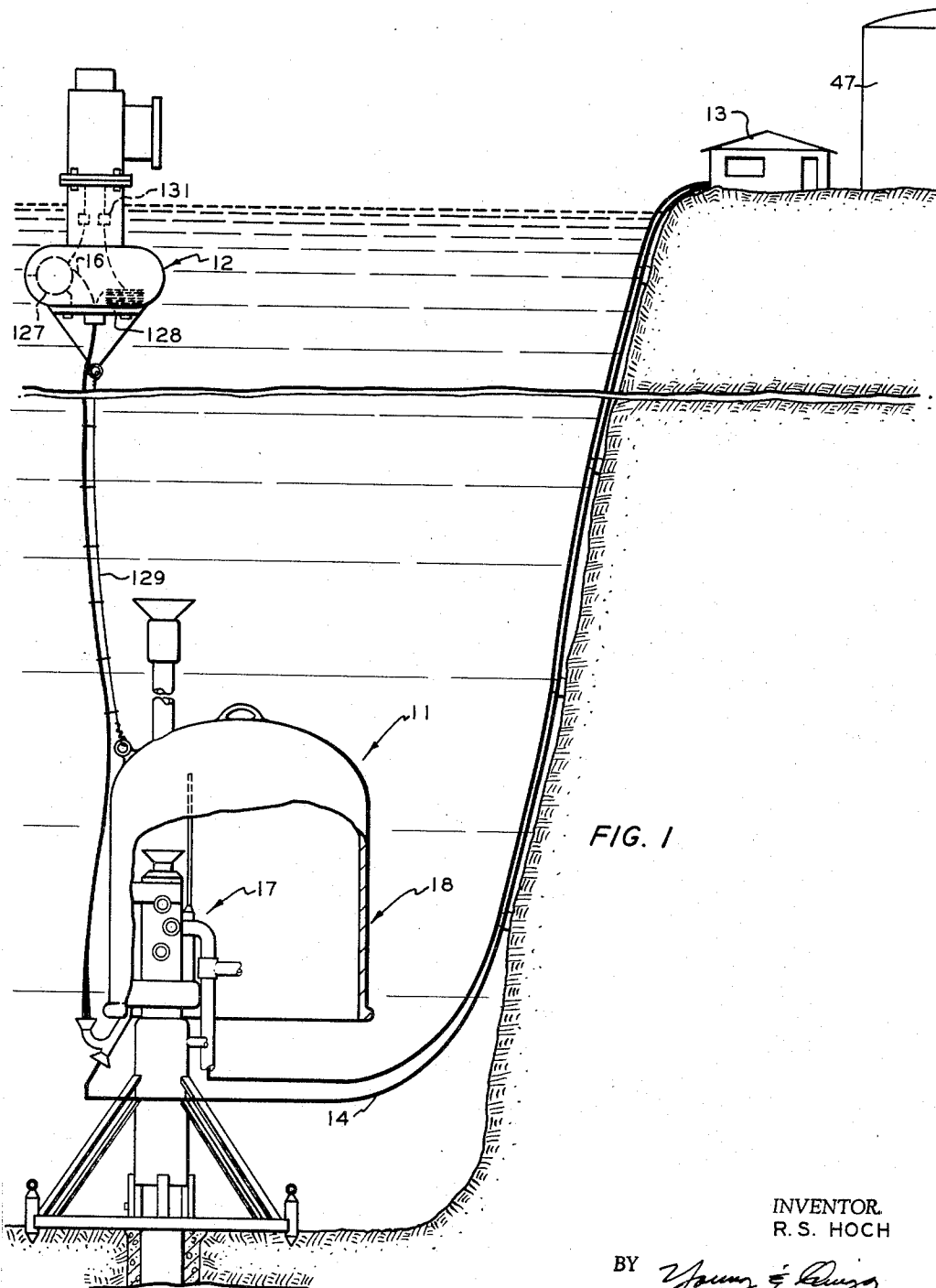


FIG. 1

INVENTOR.
R. S. HOCH

BY

Young & Co.

ATTORNEYS

Oct. 12, 1965

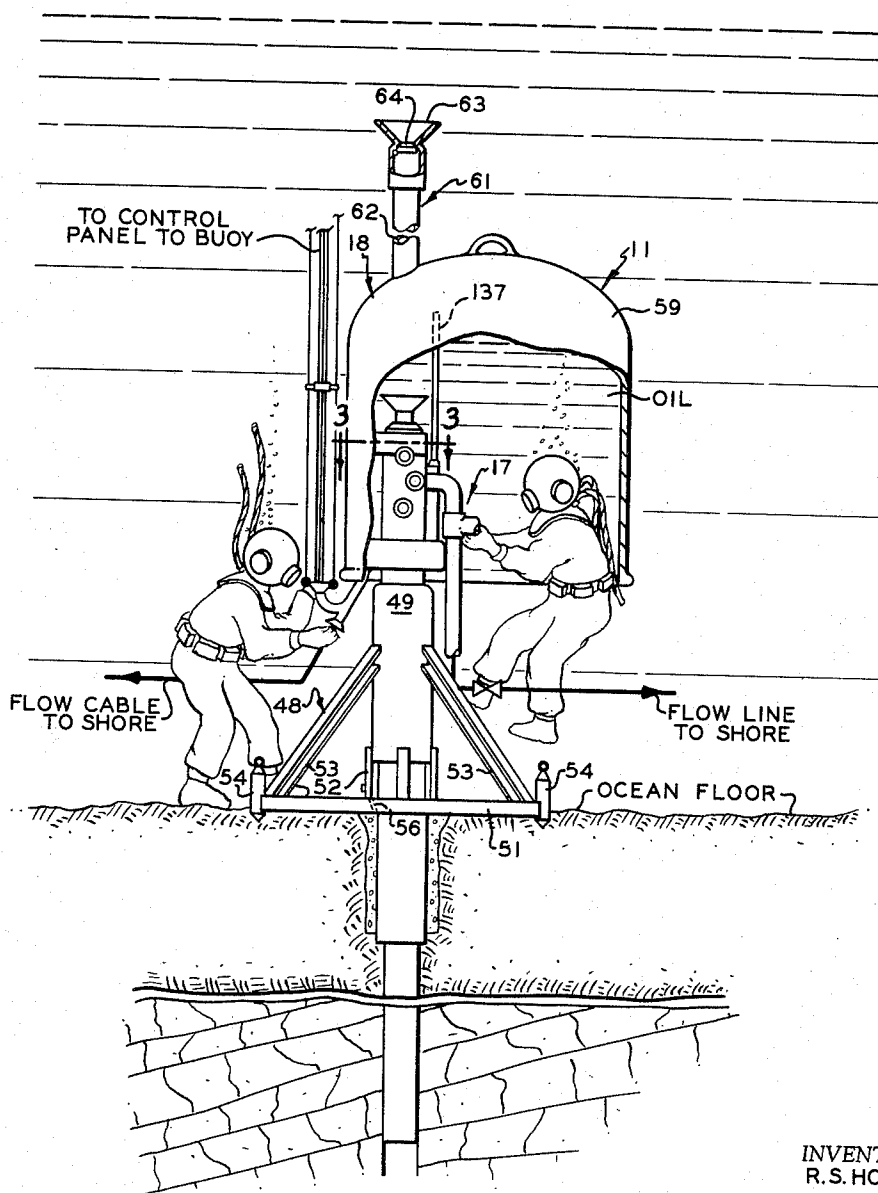
R. S. HOCH

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INVENTOR.
R.S. HOCH

BY *Young & Rugg*

ATTORNEYS

Oct. 12, 1965

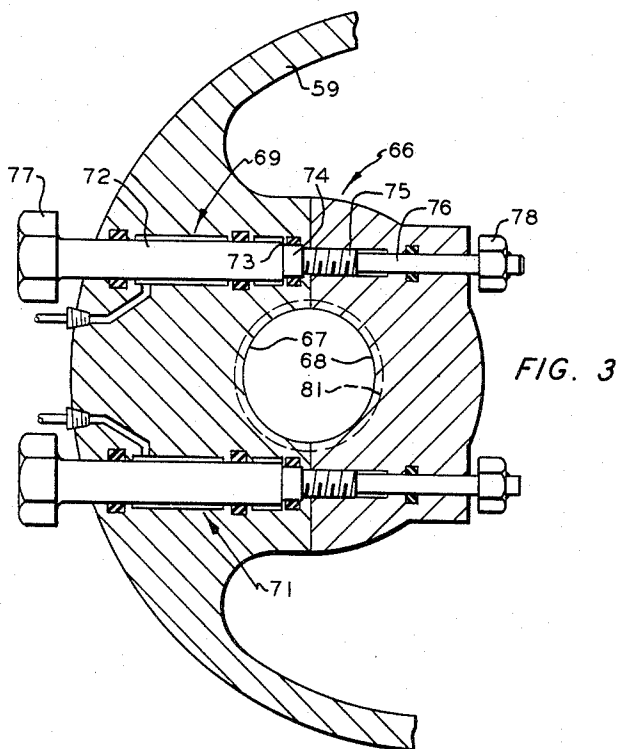
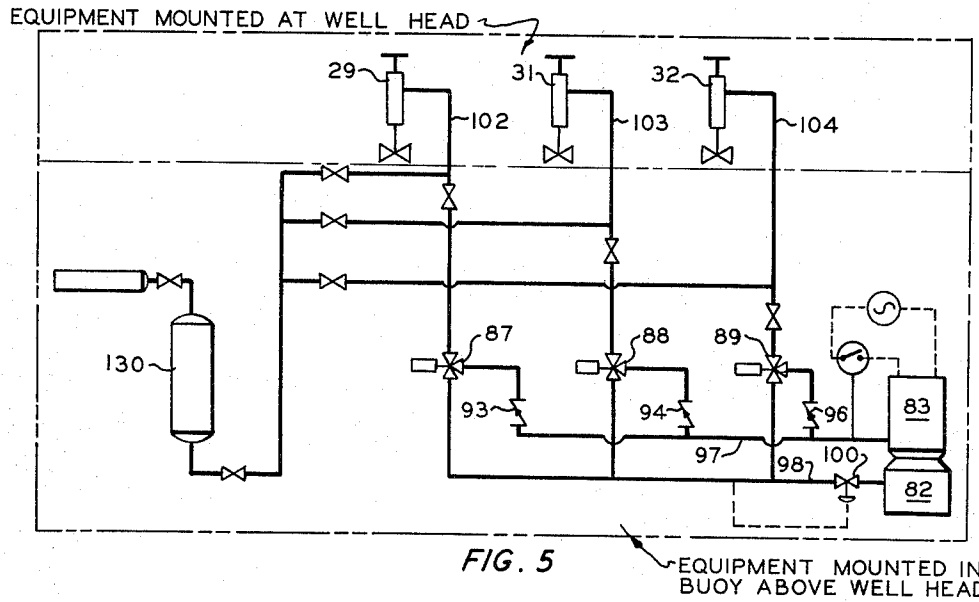
R. S. HOCH

3,211,223

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6 Sheets-Sheet 3



INVENTOR.
R. S. HOCH

BY *Young & Co.*
ATTORNEYS

Oct. 12, 1965

R. S. HOCH

3,211,223

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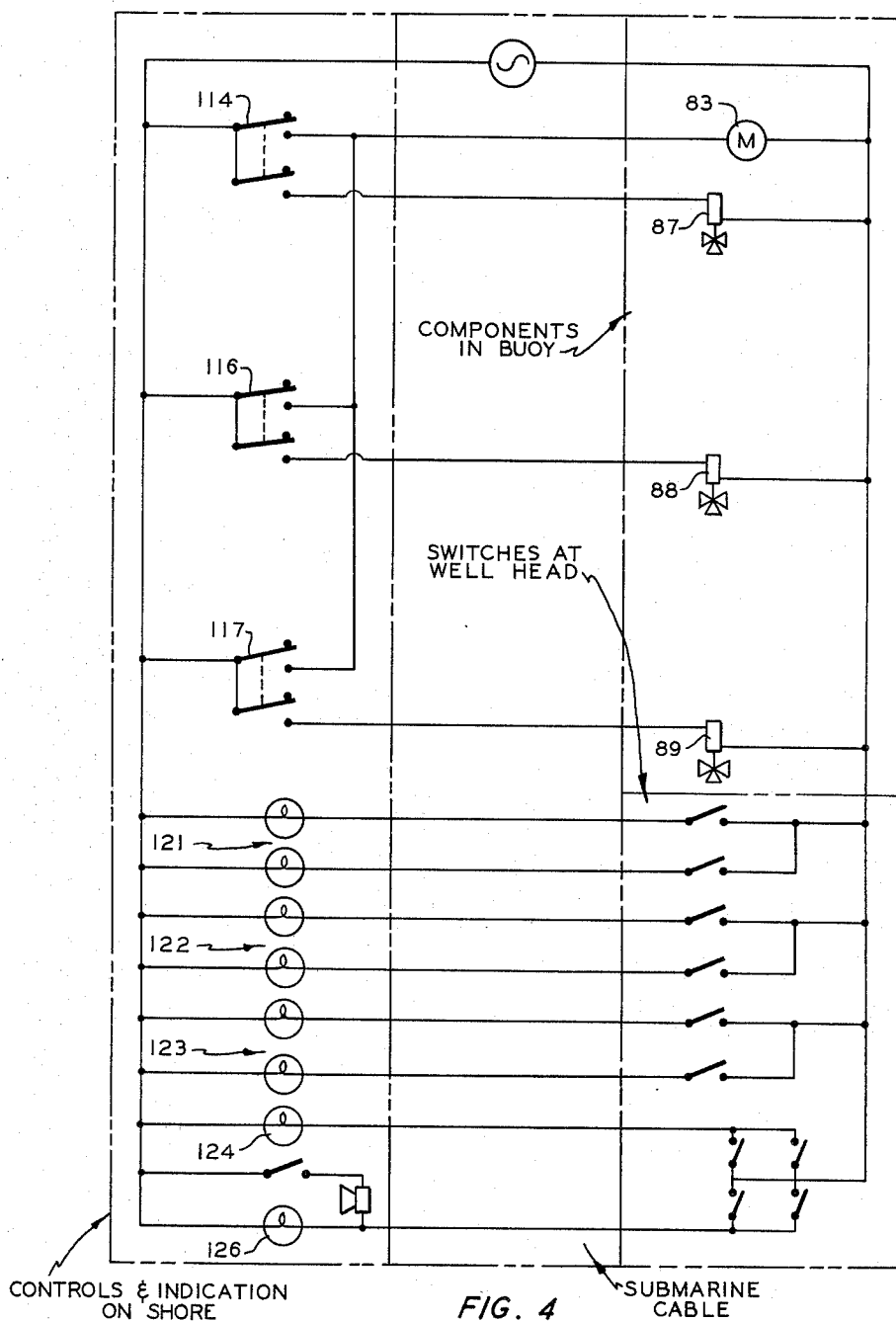


FIG. 4

INVENTOR.
R. S. HOCH

BY *Young & Rigg*
ATTORNEYS

Oct. 12, 1965

R. S. HOCH

3,211,223

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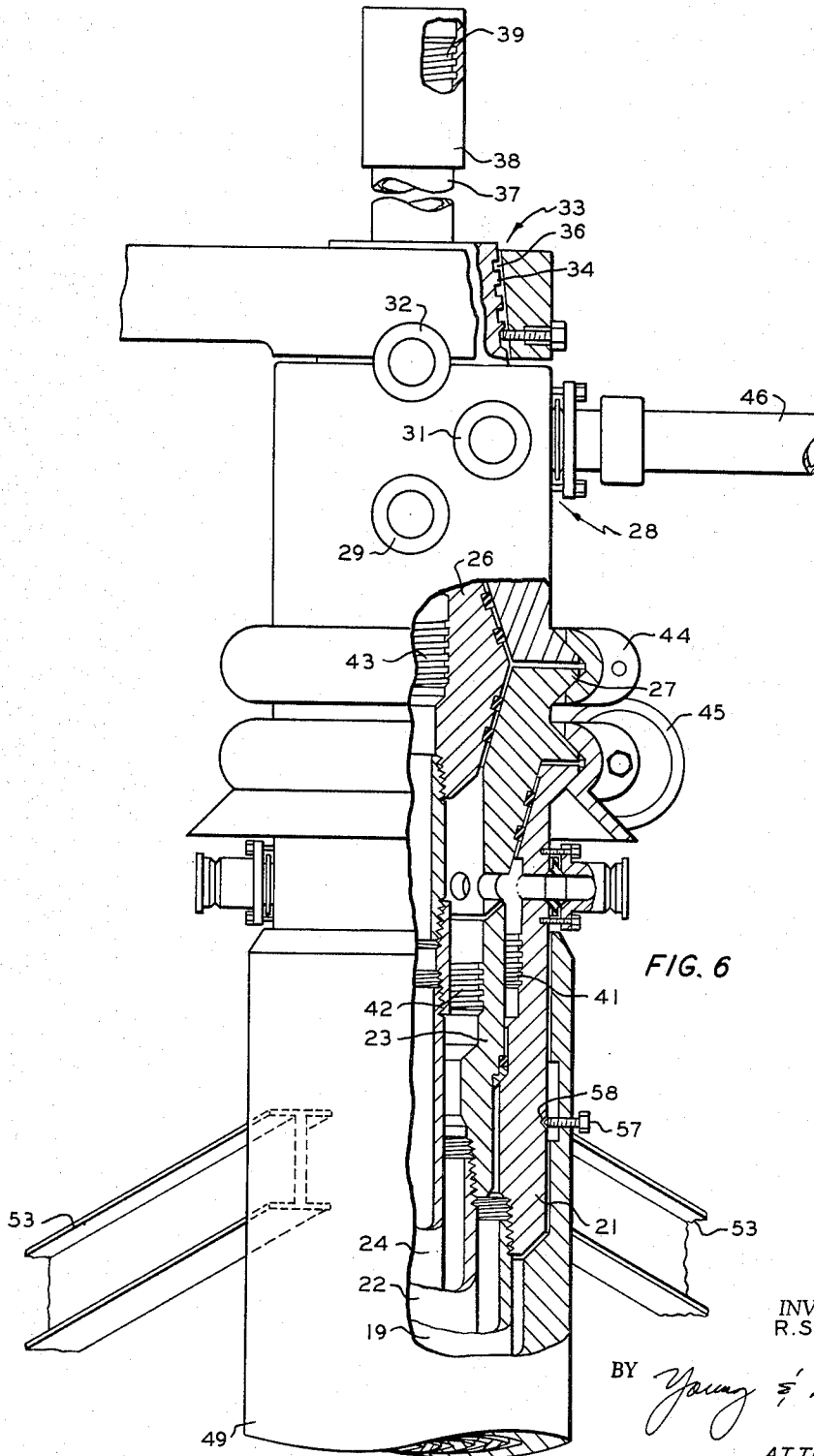


FIG. 6

INVENTOR.
R.S. HOCH

BY *Young & Bugg*
ATTORNEYS

Oct. 12, 1965

R. S. HOCH

3,211,223

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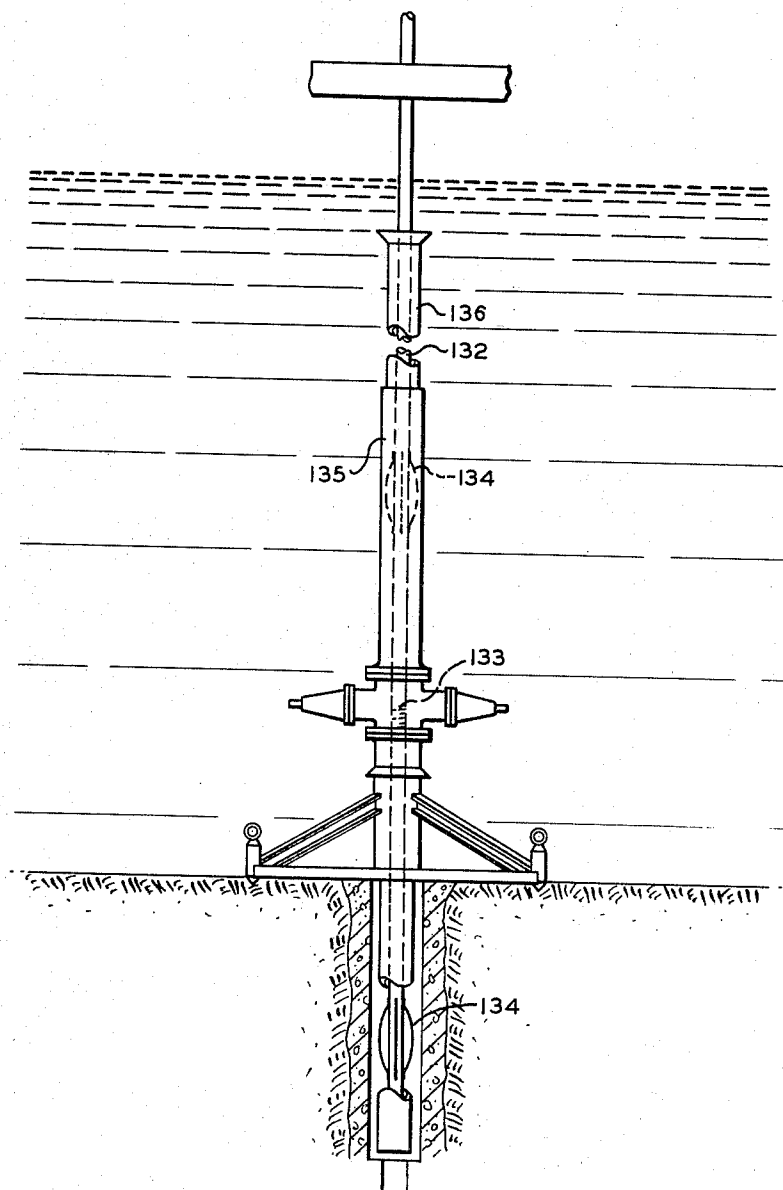


FIG. 7

INVENTOR
R. S. HOCH

BY

Young & Rugg

ATTORNEYS

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3,211,223

UNDERWATER WELL COMPLETION

Robert S. Hoch, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

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7 Claims. (Cl. 166-66.5)

This invention relates to underwater ocean floor wells. In one aspect the invention relates to method and apparatus for completing wells on the ocean floor. In another aspect this invention relates to an improved underwater wellhead assembly. In another aspect this invention relates to novel wellhead protective apparatus and method. In another aspect this invention relates to method and apparatus for work over of subsea petroleum wells.

In the production of petroleum from deposits lying under offshore locations, many wells have been completed from platforms built above the surface of the water, resting on subaqueous supporting members. In such completions the Christmas tree and associated equipment are supported on the platform, above the water. Although, in many instances, such well completions have operated satisfactorily, many times there are advantages to be gained by placing all of the wellhead assembly underwater, on the ocean floor. By completing the well underwater, the need for expensive, difficult to maintain platforms and possible interference with shipping are avoided and the wellhead is located at a point protected from damage due to collision or storm. When the wellhead is placed on the ocean floor it is necessary to prevent excessive corrosion of the various parts of the head due to contact with the sea water, and it is desirable to provide for ease of completion of the well and for ready access for work over.

An object of this invention is to provide economical and improved underwater well completions.

Another object of this invention is to provide method and means for completing underwater wells.

Another object of this invention is to provide improved underwater wellhead assemblies.

Another object of this invention is to provide novel wellhead protective method and apparatus.

Another object of this invention is to provide ready access of an underwater well for work over.

Other aspects, objects and the advantages of my invention are apparent from the written description, the drawing and the claims.

In the drawing:

FIGURE 1 is a schematic elevation, partly in cross section, of an underwater wellhead assembly according to my invention and the associated buoy, onshore control station and connecting conduits and conductors.

FIGURE 2 is a schematic elevation, partly in cross section, of the wellhead assembly of FIGURE 1, showing divers at work on the assembly.

FIGURE 3 is a horizontal cross section taken along the line 3-3 of FIGURE 2.

FIGURE 4 is a schematic circuit diagram of an electrical control system.

FIGURE 5 is a schematic diagram of a hydraulic system.

FIGURE 6 is an elevation, partly in cross section, illustrating details of the casing head and Christmas tree assembly portion of the wellhead assembly.

FIGURE 7 is a schematic elevation of a portion of the assembly during installation, illustrating the use of a lowering tube.

As shown in FIGURES 1, 2, 3 and 6, the complete installation comprises a wellhead assembly 11, a buoy 12, and a shore control station 13, electrical connecting cable

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14 from a shore to assembly 11, and buoy 12 and hydraulic lines 16.

Assembly 11 includes wellhead 17 and protective bell housing 18.

Referring particularly to FIGURE 6, the wellhead and associated equipment comprising the complete wellhead assembly comprises a surface casing 19 to which is attached to casing head 21. An oil string 22 is supported by sealing member 23 which is supported by an inner portion of head 21. Tubing 24 is carried by inner seal member 26 and outer seal member 27. Valve block assembly 28 also provides a seal with inner seal member 26 as shown and carries master valve 29, wing valve 31, lubricator valve 32 and access head 33. Access head 33, as illustrated in FIGURE 6, is made integrally with valve block assembly 28 and comprises a tapered surface 34 in which are formed a series of annular indentations 36. A heavy wall sub 37 is provided with a collar 38 which includes square-cut, left-hand threads 39. Casing head 21, sealing member 23 and inner seal member 26 also are provided with square-cut, left-hand threads 41, 42 and 43, respectively. Inner and outer seal members 26 and 27, valve block assembly 28 and access head 33 together form a unitary Christmas tree assembly which is held together by clamp 44 and which supports tubing 24. Flow line 46 connects wellhead assembly 11 with onshore storage facilities 47, or can be connected with a remote producing platform facility.

Wellhead assembly 11 also includes wellhead anchor 48 which comprises rigidity sleeve 49, base 51, legs 52, diagonal braces 53 and anchor points 54. The combination of rigidity sleeve 49, legs 52, base 51 and wedge members 56 provides a bracing structure to support the threaded connection between casing head 21 and surface casing 19 to prevent failure of the structure at this point. Although the anchor assembly is illustrated with a rigidity sleeve 49 and separate legs 52, a single cylindrical member can be used to serve both as the sleeve and the legs, hand openings being provided for insertion of wedge-type centering members 56. Alternatively, the rigidity sleeve 49 can be made as shown and legs 52 formed of a single short section of casing. Rigidity sleeve 49 is anchored to casing head 21 by wedge bolts 57 which cooperate with a groove 58 in head 21.

In FIGURE 2, wellhead assembly 11 further comprises bell housing 18 which includes a generally cylindrical shell 59, closed at the top and open at the bottom as illustrated, which covers wellhead 17. Shell 59 is provided with an access connection 61 in the top thereof, said connection 61 comprising a pipe 62, a guide funnel 63 and a flapper-type check valve 64. Shell 59 is attached to wellhead 17 by clamping means 66. Clamping means 66 comprises one split ring section 67 rigidly attached to shell 59, as by welding, shown in FIGURE 3 as an integral part of shell 59, and a second split ring section 68 which is free to move relative to section 67. A pair of fasteners 69 and 71 attach the two split ring sections together and provide for tightening the head on the upper portion of tapered surface 34 of wellhead 17. Fastener 69 is provided with a cylindrical surface 72, a shoulder 73, a cylindrical surface 74 of smaller diameter, a threaded section 75, and a smaller diameter cylindrical section 76. Thus, fastener 69 can be inserted from the outside until the threaded section 75 engages a corresponding threaded section of split ring section 68. With shoulder 73 engaging the corresponding surface of split ring section 65, further rotation of fastener 69 draws split ring section 68 toward section 67 to engage surface 34. Fastener 69 is provided with a first wrench-engaging surface 77 which can be made integrally with the fastener 69, and a second wrench-engaging surface 78 which can be attached, as by threads and welding, after fastener 69

has been inserted into operating position. Thus, the clamping means can be tightened or loosened either from inside or outside shell 59. Fastener 71 is in all particulars similar to fastener 69. Preferably, surface 34 is provided with a plurality of annular indentations 36 and the split rings 67 and 68 provided with matching protrusions 81 to provide a more positive vertical attachment with wellhead 17.

Buoy 12 contains hydraulic oil reservoir 82, motor-driven hydraulic pump 83 and solenoid valves 87, 88 and 89 (see FIGURE 5). Check valves 93, 94 and 96 are provided as shown. Oil under pressure is supplied through pipe 97 and with the corresponding solenoid deenergized, returns through each of the 3-way solenoid valves to return pipe 98. With the corresponding solenoid valve deenergized, each of the pipes 102, 103 and 104 is relieved of pressure and the corresponding wellhead valves 29, 31 and 32 closed. Of course, additional valves can be utilized where desired and other hydraulic units such as, for example, a paraffin scrape inlet, can be installed for operation by this hydraulic system.

Each of the solenoid valves 87, 88 and 89 is actuated by an electrical circuit, controlled by switches 114, 116 and 117 in onshore facilities 13 (see FIGURE 4). When the corresponding switch is closed a circuit is completed to one of the solenoid valves, thus changing the position of this valve to permit hydraulic fluid under pressure to be supplied to the corresponding well valve thus opening that valve. Back pressure valve 100 is provided and is set to a desired pressure to permit pressure build-up for operation of the wellhead valves even though other well valve actuation circuits are set to by-pass fluid to the reservoir. When the switch is open the circuit to the corresponding solenoid is broken, which permits the pressure to be reduced at the wellhead valve, permitting this valve to close. Each of the wellhead valves has corresponding position indicators 121, 122 and 123 actuated by limit switches in each valve. Casing and line pressure alarms and indicators are provided at 124 and 126.

In the lower portion of buoy 12 there is provided a spring-loaded reel 127 on which are wound the hydraulic line 16 and connecting cable 14 leading to the upper portion of the buoy which contains electric and hydraulic equipment. This permits removal of the upper portion of the buoy for replacement or repair without disconnecting the cables and hydraulic lines since they merely are unreeled from reel 127. Reel 127 is attached to a plate 128 which is held in the lower portion of buoy 12 by shear bolts. Thus, a displacement of buoy 12 causes plate 128 to be pulled free of the buoy by anchor cable 129; further displacement of the buoy causes all of the hydraulic lines and electrical conductors to be pulled free at a shear connection indicated generally at 131, at which time all of the cables and reel fall to the ocean floor from which point they can be recovered later. Also located in buoy 12 is a pressurized hydraulic reservoir 130, illustrated schematically in FIGURE 5. This can be, for example, a pressure vessel containing hydraulic fluid and a container of nitrogen under pressure which can be released into the vessel to apply pressure to the fluid. This permits hydraulic operation of the valves from the buoy, even if the shore connection should be broken. It is preferred that the wellhead valves, such as valves 29, 31 and 32, be valves which can be operated manually, as well as by hydraulic pressure, to permit their operation by divers if all connection with the buoy is broken. Suitable valves of this type are made by W-K-M Division of ACF Industries, Inc., Houston, Texas, and shown in catalog supplement sheet for Catalog 200, page 17. For this service the valves should be "fail closed," that is, the valves should close automatically upon failure of hydraulic pressure.

In operation, after the surface hole has been drilled, the surface casing is lowered into the hole with head 21 attached thereto and with blowout preventers attached to the top of this when drilling with a floating type drilling

barge. Base 51, legs 52, braces 53, anchor points 54, held in place by wedge members 56 and wedge bolts 57, are installed at this time. This entire assembly is lowered by a lowering tube such as lowering tube 132 illustrated in FIGURE 7. This tube comprises left-hand threads 133 on its lower end. Similar lowering tubes are used for lowering subsequent strings of casing and tubing and, in those instances, a centering means 134 is provided.

After the casing and anchor means are landed, lowering tube 132 is released therefrom by rotation to the right. The hole is then drilled to the depth required for the oil string 22 and this string lowered by means of a similar lowering tube in which threads 133 are the proper size to engage the threads 42. During this operation centering means 134 are contacted by a stiff portion 135 of the pipe 136 which extends from the blowout preventers to the surface of the water to prevent damage of the sealing surfaces as they are lowered through the blowout preventers. Although more than one centering device is shown, in many instances a single such unit located immediately above the left-hand threads is sufficient. After this string is cemented into place the blowout preventers are removed and the entire remaining portion of the wellhead assembly is then lowered into place with tubing 24 attached. Normally, a packer (not shown) will be installed on the lower end of tubing 24. After the entire remaining portion is lowered into place, hydraulic clamp 45 is utilized to attach the portions together. During this time, a lowering tube having threads corresponding with the threads in the upper portion of access head 33 is utilized, and after the entire installation is attached to casing head 21 on the floor of the ocean this pipe is removed by rotating to the right and raising through flapper valve 64. During this operation it is preferable that a diver be present at the well head to complete the clamping operation, etc. After the entire installation is completed and the diver removed therefrom, a protective fluid is pumped downward through a conduit (not shown) which connects with oil fill line 137 which terminates near the top of shell 59. The protective fluid being lighter than sea water, the water is forced out of the bottom of shell 59 until the protective fluid completely fills the space within.

When it becomes necessary to repair the well, it is possible to use concentric tubing or rod-type work over tools without having access to the wellhead itself simply by lowering these tools from the surface through funnel 63 and valve 64, through lubricator valve 32 and master valve 29 into tubing 24. If more serious work is necessary the protective fluid within shell 59 can be removed through fill line 137 and various portions of the wellhead removed, depending on the circumstances. For example, the entire upper assembly can be removed by loosening clamp 45 and withdrawing the entire upper unit including shell 59. Alternatively, shell 59 can be removed by loosening fasteners 69 and 71 and lifting this shell from the wellhead. Clamp 44 can be removed, thus permitting the removal and the reinsertion of tubing 24 with a lowering tube attached to threads 43, leaving the remaining portion, including outer seal member 27 in the well. If it is necessary to have access to the connections around valve block assembly 28, clamps 44 and 45, etc., room is provided due to the eccentric positioning of shell 59 for access by a diver who enters through the lower open portion of this shell, the protective fluid being removed if desired or if necessary.

Reasonable variation and modification are possible within the scope of my invention which sets forth method and apparatus for providing subsea well completions and for reworking the well when necessary.

I claim:

1. An underwater wellhead assembly comprising a wellhead, an inverted bell housing located over said head, said housing being generally circular in horizontal cross section and open on the bottom to provide free access to said head, and means to attach said housing to said head

eccentrically to provide working space around one side of said head.

2. An underwater wellhead assembly comprising a wellhead, an inverted bell housing located over said head, said housing being generally circular in horizontal cross section and open on the bottom to provide free access to said head, means to attach said housing to said head eccentrically to provide working space around one side of said head, an access connection in the top of said housing coaxial with said head, a flapper-type check valve in said connection, and a top opening on said head coaxial with said head.

3. An underwater wellhead assembly comprising a wellhead comprising a lower casing head, a casing supporting said wellhead, an inverted bell housing located over said head, said housing being generally circular in horizontal cross section and open on the bottom to provide free access to said head, means to attach said housing to said head eccentrically to provide working space around one side of said head, and a wellhead anchor comprising a rigidity member reinforcing the connection between said lower casing head of said wellhead and said casing to which it is connected, a base resting on the ocean floor and bracing means uniting said rigidity member and said base into a rigid unitary structure.

4. An underwater wellhead assembly comprising an outer casing string, a wellhead, said head comprising a lower portion attached to said outer casing string and an upper portion, a well control valve supported on said upper portion, hydraulic clamp means to attach said upper portion to said lower portion, an inverted bell housing located over said head, said housing being generally circular in horizontal cross section and open on the bottom to provide free access to said head, and means to attach said housing to said head eccentrically to provide working space around one side of said head.

5. An underwater wellhead assembly comprising a wellhead, said head comprising a lower portion attached to an outer casing string and an upper portion which supports a well control valve, hydraulic clamp means to attach said upper portion to said lower portion, an inverted bell housing located over said head, said housing being generally circular in horizontal cross section and open on the bottom to provide free access to said head, means to attach said housing to said head eccentrically to provide working space around one side of said head, an access connection in the top of said housing coaxial with said head, a flapper type check valve in said connection, a top opening in said head coaxial with said head, a wellhead anchor comprising a rigidity member reinforcing the connection between the lower casing head of said wellhead and the casing to which it is connected, a base resting on the ocean floor and bracing means uniting said rigidity member and said base into a rigid unitary structure.

6. An underwater wellhead assembly and control means comprising a wellhead, an inverted bell housing located over said head, said housing being generally circular in horizontal cross section and open on the bottom to pro-

vide free access to said head, means to attach said housing to said head eccentrically to provide working space around one side of said head, hydraulically actuated valves in said wellhead, a buoy, means to anchor said buoy above said wellhead, said buoy comprising means for supplying high pressure hydraulic fluid, conduit means connecting said means for supplying hydraulic fluid to said valves, electrical means onshore for controlling the supply of hydraulic fluid from said buoy to said wellhead, and electrical conducting means connecting said control means with said buoy.

7. An underwater wellhead assembly and control means comprising a wellhead, an inverted bell housing located over said head, said housing being generally circular in horizontal cross section and open on the bottom to provide free access to said head, means to attach said housing to said head eccentrically to provide working space around one side of said head, hydraulically actuated valves in said wellhead, a buoy, means to anchor said buoy above said wellhead, means in said buoy for supplying high pressure hydraulic fluids, conduit means connecting said means for supplying hydraulic fluid to said valve, a self-winding reel for said conduit means, support means for said self-winding reel attached to said buoy by shear means whereby excessive movement of said buoy with respect to said wellhead shears said shear means to permit said conduit means to be released from said buoy without destroying said conduit means, electrical means onshore for controlling the supply of hydraulic fluid from said buoy to said wellhead, and electrical conducting means connecting said control means with said buoy.

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60 CHARLES E. O'CONNELL, *Primary Examiner.*