United States Patent

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Continuation of application Ser. No. 592,864, Nov. 8, 1966, now abandoned.

[54] UNDERWATER WELL COMPLETION SYSTEM

19 Claims, 7 Drawing Figs.

[52] U.S. Cl. 166/.5, 166/89
[51] Int. Cl. E21b 33/035
[50] Field of Search ..... 106/.5, .6, 75, 88, 89, 130, 242, 217

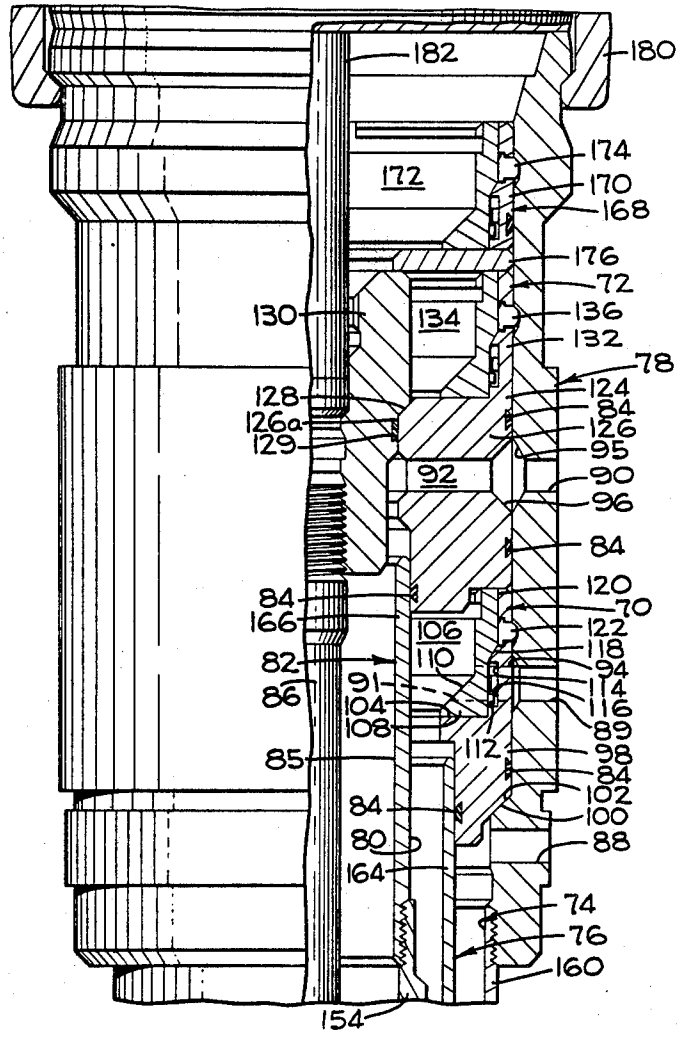
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ABSTRACT: An underwater wellhead completion apparatus in which a plurality of well casing extensions extend, having a plurality of remotely controllable tubular packoffs between the inner surface of the wellhead and the outer surface of each casing extension. A tubular production string is landed in one of the packoffs and a Christmas tree for controlling the flow in the production string is mounted on the wellhead.



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SHEET 1 OF 5

FIG. 1

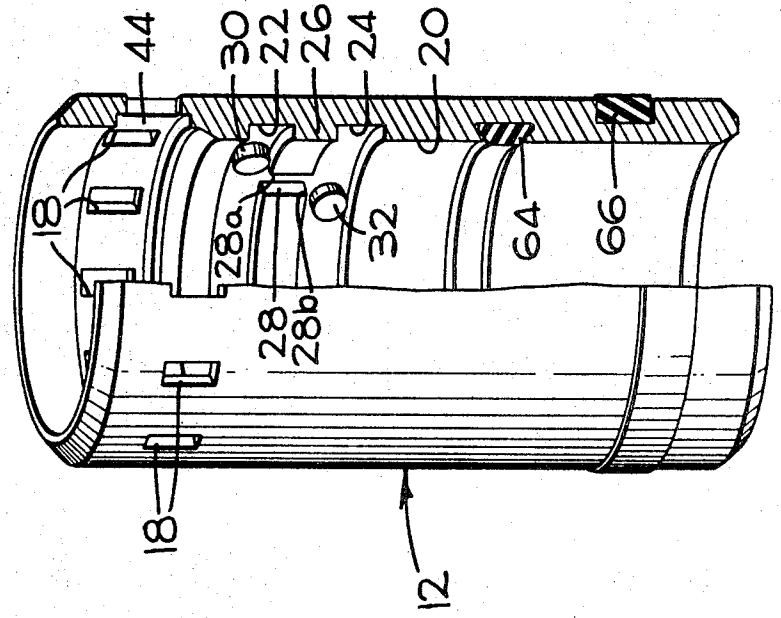


FIG. 3

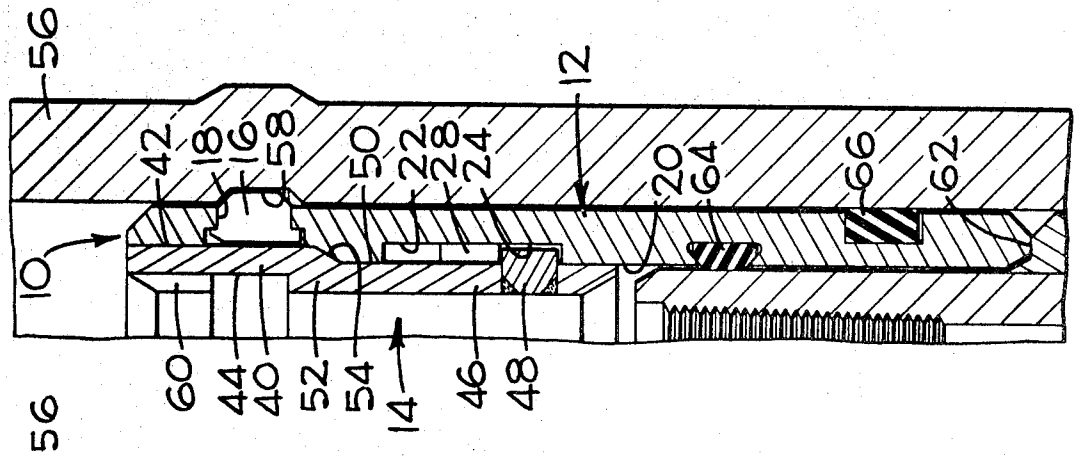
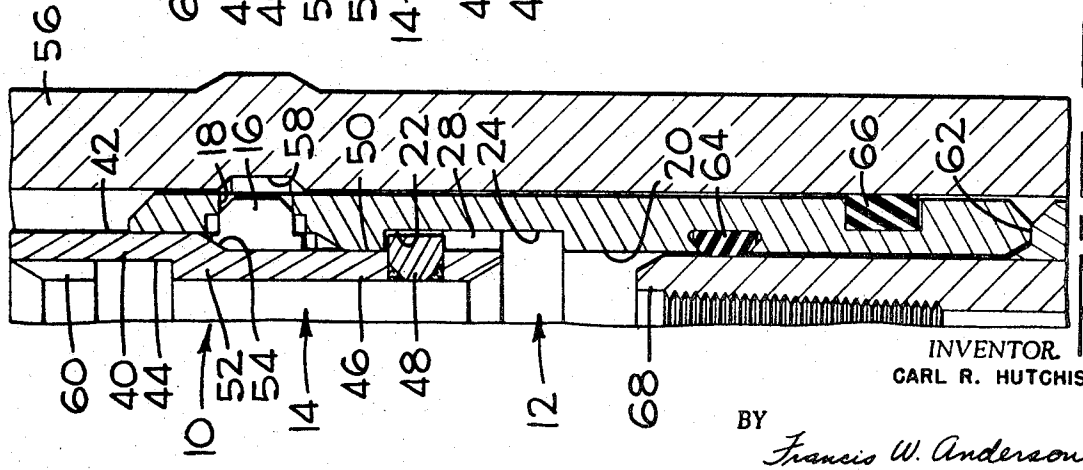


FIG. 2



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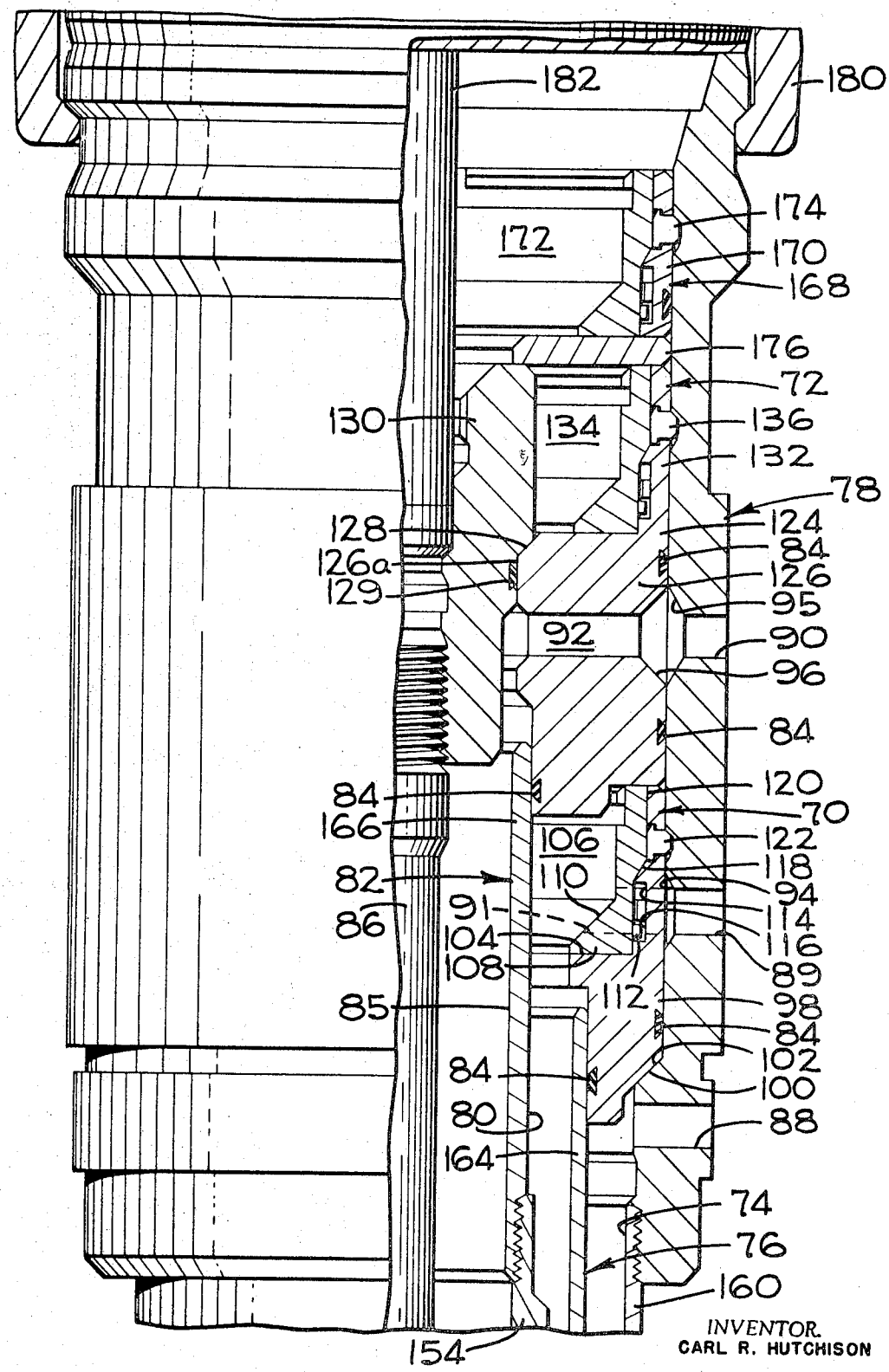


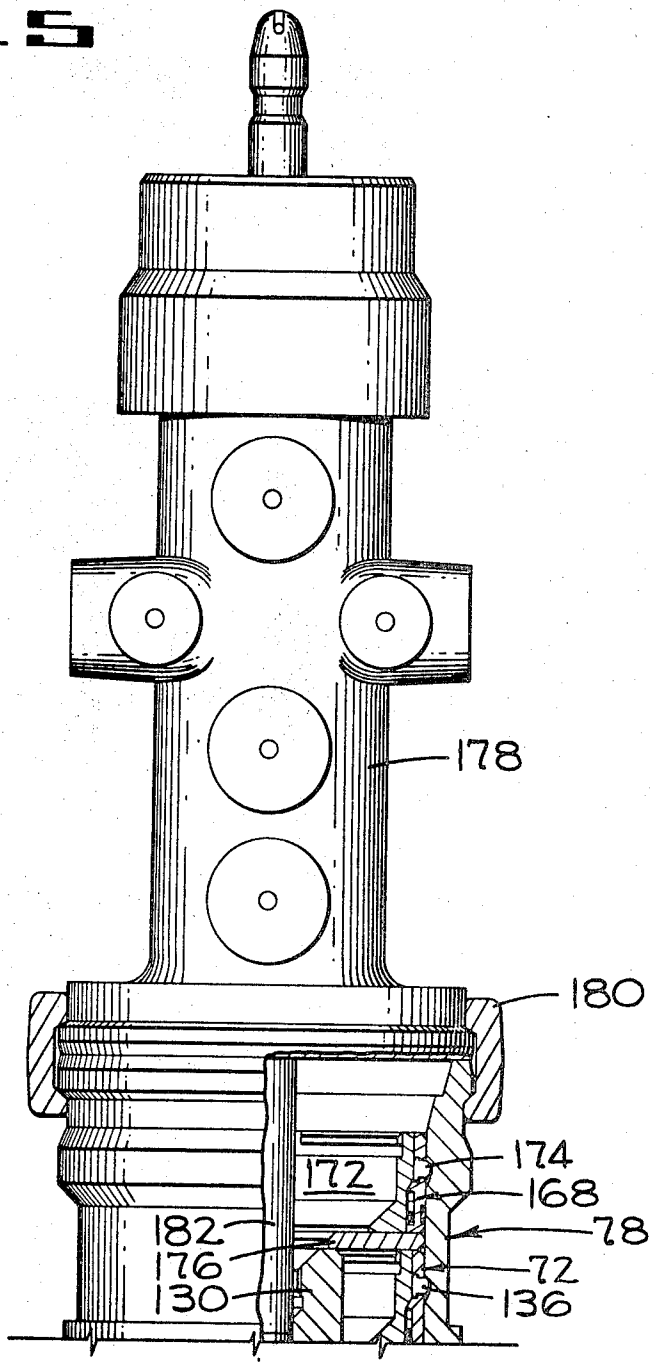
FIG_4

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FIG_5

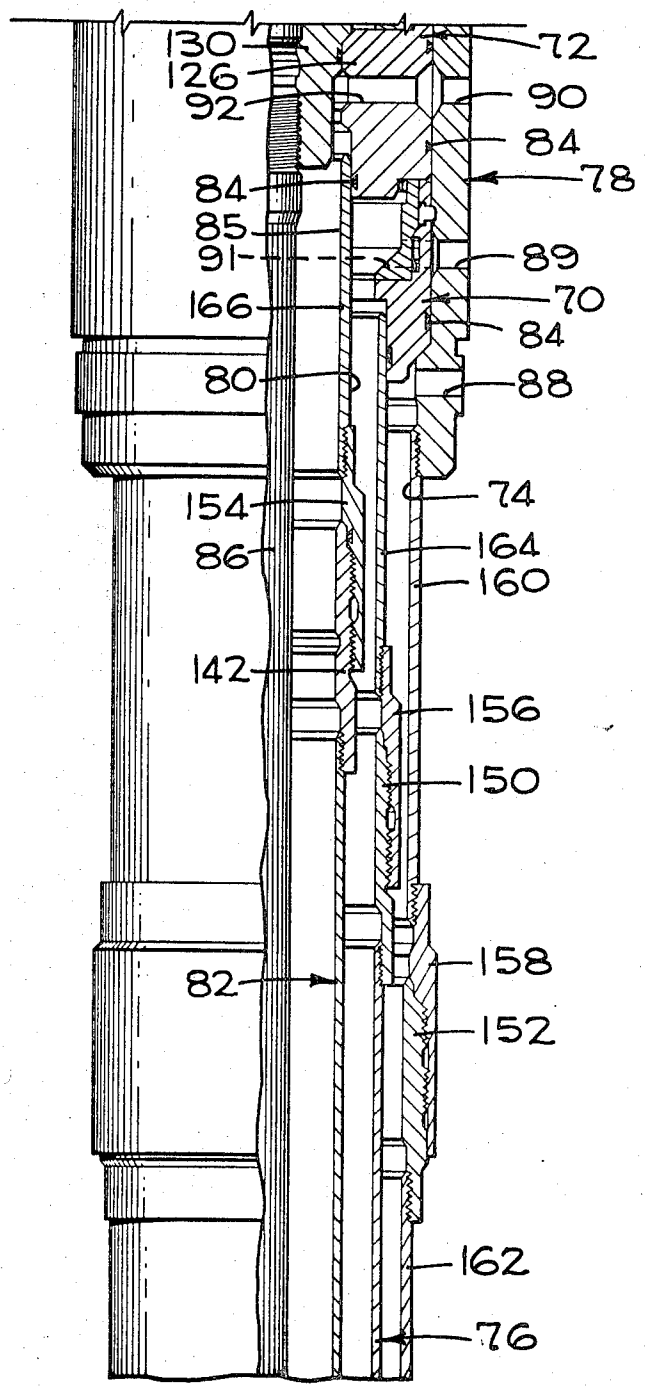


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FIG_6

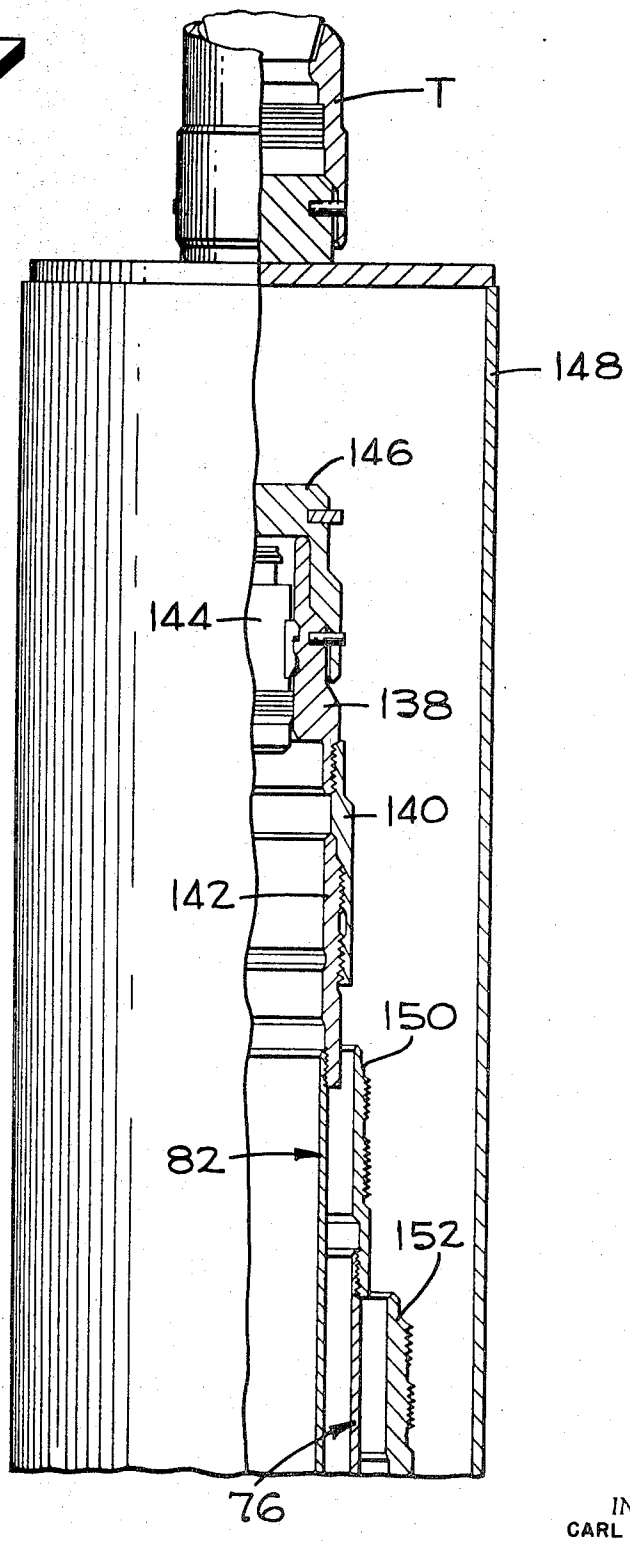


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FIG_7



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UNDERWATER WELL COMPLETION SYSTEM

This application is a continuation of application Ser. No. 592,864 filed Nov. 8, 1966, now abandoned.

This invention pertains to a system for completing an underwater well. More specifically, this invention relates to a method for completing underwater, and entirely from a remote position, a well that has been drilled and cased with ocean bottom suspension equipment, and to apparatus for use in carrying out this method.

Exploratory well drilling in offshore locations has become a significant facet of the petroleum industry, and projections for the future indicate it will retain its importance in the world-wide quest for crude oil and natural gas. When an offshore well is drilled for exploratory purposes and producible quantities of oil and/or gas are found, the well is either completed at that time or is abandoned, the latter usually on a temporary basis with the thought of reentry and completion, at a later date. An increasing number of offshore wells are being drilled and cased with so-called ocean bottom suspension (hereinafter referred to as OBS) equipment designed for suspending the casing at the ocean floor and then completing the well at the surface, for in many instances this procedure has been found desirable over other techniques for underwater well drilling, the chief one being cost.

When OBS wells are temporarily abandoned, all of the risers between the ocean floor and the surface are removed, to be replaced later when the well is completed at the surface. Such replacement can involve problems, especially in areas where weather and water conditions are apt to be uncertain and thus unsafe for diver assistance. Furthermore, when divers must be used the depth of the water is a limiting factor, even though all other conditions might be ideal. Other problems arise when an operator uses OBS equipment and then decides to complete the well at the bottom of the water, for this equipment is not designed for bottom completions.

Accordingly, a general object of this invention is to provide a new system for completing underwater wells drilled and cased with OBS equipment.

Another object of this invention is to provide a new method for underwater completion of wells drilled and cased in the OBS manner, and then temporarily abandoned.

Another object of this invention is to provide a new method for completing OBS wells at the floor of the ocean or other body of overlying water entirely by remote control from the surface.

Still another object of this invention is to provide improved apparatus for completing wells drilled and cased with OBS equipment.

A further object of this invention is to provide an improved casing packoff that can be run and set by remote control from the surface without the assistance of divers or use of hydraulic equipment. A still further object of this invention is to provide an improved type of casing packoff that can be run and set in a remote location and then retrieved therefrom, all with conventional drilling equipment.

These and other objects and advantages of the present invention will become apparent from the following description, taken with the accompanying drawings, in which:

FIG. 1 is a view in side elevation and partially in section of the body of a casing packoff according to this invention;

FIG. 2 is an enlarged fragmentary view in side elevation and in section of the packoff body of FIG. 1 and its mandrel, after it has been landed in an outer housing but before it is locked in place;

FIG. 3 is a view like FIG. 2, showing the packoff locked between the outer housing and an inner casing;

FIG. 4 is a view in side elevation and partially in section of a type of wellhead that can be used in practicing this invention, installed on a well casing and with two packoffs of this invention locked in position between the wellhead and an inner casing string;

FIG. 5 is a view in side elevation and partially in section, on a reduced scale, of the upper portion of the wellhead of FIG. 4 together with a Christmas tree installed on its upper end;

FIG. 6 is a view in side elevation and partially in section of the lower portion of the wellhead of FIG. 5, showing the connections between it and the several casing strings; and

FIG. 7 is a view similar to FIGS. 5 and 6, showing the same well as it appeared when temporarily abandoned and before completion had begun according to this invention.

Broadly considered, the method of this invention comprises: (a) running and landing a unitized wellhead on an outer casing string of the underwater OBS well at the general level of the floor of the body of water overlying the well; (b) extending the first inner casing string adjacent the outer string into the wellhead; (c) packing off the annulus between the wellhead and the first inner casing string; (d) repeating steps (b) and (c) on all remaining inner casing strings, in consecutive order from the outermost to the innermost; (e) running at least one production tubing string and landing it in the wellhead; and (f) running and landing a Christmas tree onto the wellhead and connecting it to the production tubing. Using apparatus of the type described later, this method can be carried out entirely by remote control from the surface without diver assistance, and thus the depth of the water overlying the well is not a limiting factor. Furthermore, although this method has been devised primarily for underwater completion of OBS wells that have been temporarily abandoned, it also can be employed to complete new OBS wells, i.e. those that have been drilled and cased, yet not abandoned.

As the drawings illustrate, the apparatus for carrying out this invention comprises a selection of connectors, casing extensions, landing subs and adapters, casing packoffs, production tubing, a tubing hanger, a hanger holddown, a unitized or integral wellhead, and a Christmas tree, all capable of assembly into a well completion unit and attachment to an underwater well at a subsurface location entirely by remote control. These various elements are connected to the well and to one another by manipulation of conventional well drilling equipment, particularly drill pipe and running tools, thereby obviating the need for special devices or techniques.

The packoffs used in this completion system are especially significant, both in the manner in which they are run and set, and in their cooperation with the wellhead to provide access to the annuli between the casing strings for pressure monitoring. FIGS. 1—3 illustrate one form of this type of packoff, and FIGS. 4—6 illustrate two additional forms, all of these forms embodying the same principles of locking and sealing. Perhaps these operations can best be explained by a description of the packoff of FIGS. 1—3, it being understood that the same procedures are followed with the other packoffs of FIGS. 4—6.

As illustrated in FIGS. 1—3, the packoff 10 comprises a generally elongated tubular body 12, a tubular mandrel 14 slidably circumscribed by the body 12, and a plurality of locking dogs 16 slidably positioned in ports 18 that extend through, and are circumferentially spaced around, the body 12. The inner or bore surface 20 of the body 12 contains an upper annular groove 22, a lower annular groove 24, and an intermediate shoulder 26, the shoulder 26 being of equal diameter with the aforesaid bore surface 20. A plurality of axially extending slots 28 extend through the shoulder 26 and form a passageway between the grooves 22, 24, and tangentially adjacent the extensions of the sides of the slots 28 are a plurality of radially inward projecting stop pins 30 and 32 (FIG. 1), the pins 30 tangentially adjacent an upward extension of the right-hand side 28*a* of the slots 28 when the body is viewed in its conventional upright position, and the pins 32 tangentially adjacent a downward extension of the left-hand side 28*b* of the slots 28. As will be described later, these grooves, slots, and pins cooperate with the mandrel 14 in running and setting, and also in retrieving, the packoff.

As shown in FIGS. 2 and 3, the mandrel 14 has an upper locking section 40 with an outer surface 42 and an inner annular groove 44, a lower section 46 of smaller outside diameter than the locking section 40 and with a plurality of ears 48 projecting radially outward from its external surface 50, and an

intermediate section 52 with an upwardly and outwardly extending camming surface 54.

When the body 12 and the mandrel 14 are assembled in the unlocked condition (FIG. 2), i.e., the condition in which the packoff 10 exists as it is being run into or retrieved from a well, the lower section 46 of the mandrel 14 opposes the locking dogs 16, and the ears 48 extend into the upper groove 22 in the body 12. From this condition the packoff 10 can be set in a housing 56, such as a unitized wellhead of the type disclosed in the copending W. L. Todd U.S. Pat. application, Serial No. 446,788, filed Apr. 2, 1965, now U.S. Pat. No. 3,299,958, assigned to the same assignee as the instant application, by rotating the mandrel 14 to the right (i.e., clockwise when viewed from the top) until the ears 48 contact the stop pins 30, lowering the mandrel until the ears 48 pass downward through the slots 28 into the lower groove 24 (FIG. 3), and then rotating the mandrel further to the right until the ears 48 come to rest against the stop pins 32. As the mandrel 14 moves downwardly in the body 12, the camming surface 54 forces the locking dogs 16 radially outward until they project through the ports 18 into an annular groove 58 in the housing 56, locking the packoff 10 into this housing 56.

As is readily apparent from the foregoing description, the packoff 10 is mechanically run and set, and thus there is no need for hydraulic lines or other cumbersome or inexpensive manipulating means. A plurality of axially extending slots 60 in the upper end of the inside surface of the mandrel 14 provide access for pins on a conventional J type running tool (not shown) to the groove 44, facilitating installation and retrieval of the packoff 10 by such a tool and a drill string (not shown) to which it can be attached.

The locking dogs 16 serve to lock the packoff 10 in its housing against upward movement, the packoff body 12 being landed on a shoulder or other stop means 62 that prevents further downward movement of the device. Inner and outer annular resilient packing members 64 and 66, respectively, which can be single units as shown or a plurality of units, provide a pressuretight seal between the packoff, an inner casing string 68, and the outer housing 56, respectively.

As illustrated in FIGS. 4—6, the cross-sectional configuration of the packoffs correspond to the configurations of the various housings into which they are set, and with the various well tools that they might support or that might support them. For example, they can be shaped like the two packoffs 70 and 72, shown best in FIG. 4, which are designed for use in a unitized wellhead such as that described in the aforementioned Todd application. As is readily apparent, the packoff 70 seals the annulus 74 between the unitized wellhead 78 and the first inner casing string 76, which could be the protection string, and the packoff 72 seals the annulus 80 between the wellhead 78 and the next inner casing string 82, which could then be the oil string. This sealing is effected through inner and outer packings diagrammatically illustrated at 84, it being understood that these packings 84 can be singular or plural, and of other configurations, all as desired.

In order to be able to monitor the pressure in the annuli 74, 80, and 85, the latter being located between the second inner casing or oil string and the production tubing 86, lateral ports 88, 89 and 90 are provided in the wellhead 78, and similar ports 91 (indicated by dotted lines) and 92 in the packoffs 70, 72, respectively. The ports 91, 92 in the packoffs 70, 72 do not have to be coaxial with the ports 89, 90 in the unitized wellhead 78, since the wellhead is provided with annular grooves 94, 95 that extend circumferentially and thus permit continuous fluid circulation between the ports 90, 92 and 89, 91, regardless of orientation of the packoffs 70, 72. Another circumferential groove 96 in the packoff 72 cooperates with the groove 95 to provide a larger passageway between the ports 90, 92 to accommodate fluids that might flow into or out of the annulus 85. Although they are not shown, conventional pressure or fluid conducting lines are attached to the outer ends of the ports 88, 89, 90 before the wellhead 78 is run.

As is shown best in FIG. 4, both packoffs 70, 72 comprise bodies, mandrels, and locking dogs which cooperate with each other just as do their counterparts in the packoff 10. In packoff 70, the body 98 has a lower shoulder 100 which serves to support the packoff in the wellhead 78 when it is landed on the wellhead's radially inward projecting seat 102, and an upper radially inward projecting surface 104 which provides a stop and seat for the mandrel 106. Except for a lower portion 108 that extends radially inward, thus providing a seat 110 upon which a well tool can be landed if desired, that mandrel 106 is shaped identically to the mandrel 14 in the packoff 10, having ears 112 that cooperate with upper and lower annular grooves 114, 116, respectively, in the body 98, and a camming surface 118 and a locking surface 120 that activate the locking dogs 122, all in a manner analogous to the packoff 10.

The body 124 of packoff 72 has a lower portion 126 shaped to accommodate the annular space between the wellhead 78 and the casing 82, to provide a seat 128 for the production tubing hanger 130, and to provide a sealing surface 126a for a seal 129 on the hanger 130. However, the upper portion 132 of the body 124 is identical to the corresponding portion of the body 98 of the packoff 70. The mandrel 134 and the locking dogs 136 are shaped identically to their counterparts 106, 122, respectively, of packoff 70, so that the procedure for locking the packoff 72 into the wellhead 78 is the same as that for locking packoff 70 in this wellhead.

For purposes of illustrating the method of completing an OBS well according to this invention, attention is directed to FIGS. 4—7 of the drawings. As a brief background preparatory to describing this method, after the well is drilled and cased with OBS equipment, the conductor pipe and all of the casing risers between the ocean floor and the surface are removed and, using a J latch running tool T (FIG. 7), a temporary abandonment cap 138 attached to a landing sub 140 is connected to a landing adapter 142 that has been left on the end of the oil string 82, a back pressure valve 144 is set in the cap 138, a temporary abandonment cover 146 is installed over the cap 138, and a corrosion cover 148 is then installed with a remotely controllable coupling (not shown) to the top of the conductor pipe (not shown) that extends into the ocean floor. As is evident from FIG. 7, landing adapter 150 on the protection string 76 and landing adapter 152 on the intermediate string (not shown) are left in place when the well is abandoned. In the usual manner, each of the landing adapters 142, 150, and 152 have a pair of Acme threads, one right-hand and the other left-hand, so that right-hand rotation breaks the connection between the adapters and the risers (not shown), and makes up the tieback subs 154, 156 and 158 (FIG. 6) into these adapters 142, 150, and 152, respectively.

With the foregoing brief background, the method for completing the well now will be described. First the corrosion cover 148 is removed and a unitized wellhead, such as 78, to which has been attached a casing extension or nipple 160 and tieback sub 158, is landed on the intermediate string 162 by making up the tieback sub 158 into the landing adapter 152. At this time, blowout preventer equipment (not shown) and risers are installed to give total protection during the following completion procedure. The abandonment cover 146, the back pressure valve 144, and the abandonment cap assembly 138 and 140 are then removed in that order.

The protection string 76 (FIG. 6) is then extended into the wellhead 78 by an extension 164 that is connected to tieback sub 156 which makes up into landing adapter 150 by right-hand rotation, and packoff 70 is then run and set between the wellhead 78 and the extended protection string 76. At this time, the annulus 74 between the wellhead 78 and the string 76 can be pressure tested via the ports 89, 91 to determine if a tight seal has been established by the packoff 70.

The oil string 82 then is extended into the wellhead 78 with extension 166 and tieback sub 154 that is made up into landing adapter 142. Packoff 72 is run and set between the wellhead 78 and the extended oil string 82, and pressure tested via ports 90, 92 to assure that annulus 80 is sealed off.

The tubing string **86** with the tubing hanger **130** are run and landed on the seat **128**, and a back pressure valve (not shown) is then run and set in the tubing hanger **130**. The tubing hanger holddown **168**, having a body **170** like the upper portions of the bodies of the packoffs **70, 72**, a mandrel **172** identical to the mandrels **106, 134** and locking dogs **174** also identical to the dogs **122, 136**, is run and set into the wellhead **78** using the same J type running tool (not shown) and technique employed with the packoffs **70, 72**, the holddown **168** landing on an annular holddown ring **176** that transmits the holding force from the holddown **168** to the tubing hanger **130**, securing it in place. A Christmas tree **178**, such as that disclosed in the Lebeaux et al. U.S. Pat. No. 3,050,126, containing a tubing hanger stinger **182**, is landed on the wellhead **78** and then fastened to it by hydraulic or other remotely controlled couplings diagrammatically illustrated at **180**, completing the well.

It is to be understood that although the foregoing description and the drawings show somewhat specific types of well equipment, such as the subs, adapters, unitized head, Christmas tree, etc. the inventive method can of course be carried out with other tools and equipment that perform or function in the same manner. Thus, the inventive method is of broad scope in that it does not depend upon use of precisely the same equipment disclosed herein.

As is evident from the foregoing, the method of this invention can be carried out entirely by remote control from the surface of the water. However, it should be understood that if for some reason diver assistance is desirable, such assistance can be employed within the spirit of the invention. For example, the Christmas tree could be mounted on the wellhead with conventional clamp-type connections or with conventional flanges, and these connections made by a diver. Therefore, the invention encompasses both techniques.

Although the best mode contemplated for carrying out the present invention has been herein shown and described, it will be apparent that modification and variation may be made without departing from what is regarded to be the subject matter of the invention as set forth in the appended claims.

I claim:

1. An underwater well completion assembly comprising:
   a. a plurality of tubular landing adapters mounted on the upper ends of a plurality of concentric tubular well strings extending into the floor of a body of water, one adapter on each spring;
   b. a plurality of tubular tieback subs mounted on the upper ends of said landing adapters, one sub on each adapter;
   c. an integral wellhead mounted on the upper end of an outer casing string circumscribing said well strings;
   d. a plurality of tubular well string extensions connected to said tieback subs and extending into said wellhead one extension to each sub, said extensions and said wellhead forming a plurality of concentric annuli;
   e. a plurality of remotely controllable tubular packoffs in said wellhead and between the inner surface of said wellhead and said extensions, one packoff between the wellhead and each extension;
   f. an inner tubular production string landed on one of said packoffs in said wellhead; and
   g. a Christmas tree mounted on said wellhead and connected to said production spring, said assembly designed for completing an underwater well at a subsurface location entirely by remote control from a surface location.

2. The assembly of claim 1 wherein each of said packoffs contains at least one lateral passage providing communication between the bore and the outer surface of said packoff, and said wellhead has a plurality of cooperating lateral ports, such that when said packoffs are properly installed in said wellhead communication between said annuli to the outside of said wellhead is established.

3. An underwater well completion assembly comprising:
   a. a wellhead unit mounted on the upper end of an outer casing circumscribing a plurality of well casing strings supported therein;
   b. a plurality of tubular well casing string extensions extending into said wellhead unit;
   c. a plurality of remotely controllable tubular packoffs in said wellhead and between the inner surface of said wellhead and said extensions, one packoff between the wellhead and each extension;
   d. an inner tubular production string landed in one of said packoffs in said wellhead; and
   e. a Christmas tree mounted on said wellhead to control flow from the inner tubular production string, said assembly designed for completing an underwater well at a subsurface location entirely by remote control from a surface location.

4. A well completion assembly including a wellhead unit mounted on the upper end of an outer well casing circumscribing an inner well casing string, tubular extension means extending said inner well casing string into said wellhead unit, and a remotely controllable well tool within said wellhead unit, said well tool comprising:
   a. an annular body having a lateral port, an inner upper annular groove, an inner lower annular groove, an axially extending slot interconnecting said upper and lower grooves, upper stop means in said upper groove adjacent the projected plane of one side of said slot into said upper groove, and lower stop means in said lower groove adjacent the projected plane of the other side of said slot into said lower groove;
   b. a mandrel positionable within the bore of said body, said mandrel having an upper outer cylindrical surface, a lower outer cylindrical surface, a lower outer cylindrical surface of less diameter than that of said upper surface, an outer intermediate camming surface extending upwardly and outwardly from said lower surface to said upper surface, and an ear projecting radially outward from said lower surface, said ear extending into said upper groove of said body when said mandrel is within said body in its unlocked position and into said lower groove of said body when said mandrel is within said body in its locked position; and
   c. a locking dog radially slidable within said port of said body and having an outer surface substantially within the confine of the outer surface of said body when said mandrel is in its said unlocked position, said wellhead unit and said well tool cooperating so that when said mandrel is moved axially downward through said body from said unlocked to said locked position said camming surface forces said dog radially outward through said port, thereby locking said well tool in said wellhead unit.

5. A well completion assembly according to claim 4, including outer annular packing means on said well tool.

6. a well completion assembly according to claim 4, including inner annular packing means on said well tool.

7. A well completion assembly according to claim 4, wherein said well tool body has a plurality of circumferential ports, and a plurality of locking dogs within said ports.

8. A well completion assembly according to claim 4, wherein said well tool body has an inner annular upwardly facing stop shoulder upon which said well tool mandrel camming surface rests when said mandrel is in its locked position.

9. A well completion assembly according to claim 4, including a plurality of said well tools positionable in said wellhead unit one above the other, each of said well tools locking directly to said wellhead unit, and at least one of said well tools providing a fluid seal between said wellhead unit and said tubular extension means.

10. A well completion assembly according to claim 4, wherein said well tool body has a plurality of axially extending, circumferentially equally spaced slots interconnecting said upper and lower grooves, upper stop means in said upper groove adjacent the projected planes of corresponding first sides of said slots into said upper groove, and lower stop means in said lower groove adjacent the projected planes of corresponding second sides of each of said slots into said lower groove.

11. A well completion assembly according to claim 10 wherein said well tool mandrel has a plurality of ears equal in number and circumferential spacing to said slots.

12. A well completion assembly according to claim 4, wherein both said wellhead unit and said well tool have at least one lateral fluid passage extending therethrough, so that when said well tool is properly installed in said wellhead unit said passages cooperate to provide a fluid flow path between the exterior of said wellhead unit and the interior of said well tool.

13. A well completion assembly according to claim 12, wherein said well tool passage extends through said body.

14. A well completion assembly according to claim 13, wherein said well tool passage extends also through said mandrel.

15. Underwater well completion apparatus comprising a well string packoff for providing a fluid tight seal between an outer tubular housing and an inner cylindrical element, said packoff comprising:

a. an elongated annular body having a plurality of circumferentially spaced ports, an inner upper annular groove, an inner lower annular groove, a plurality of axially extending, circumferentially equally spaced slots joining said upper and lower grooves, and a plurality of stop pins extending radially inward from both of said grooves, said stop pins in said upper groove positioned tangentially to the upward extension of the right side of said slots into said upper groove, and said stop pins in said lower groove positioned tangentially to the downward extension of the left side of said slots into said lower groove;

b. an elongated annular mandrel positioned within the bore of said body, said mandrel having an upper annular portion, a lower annular portion of less diameter than said upper annular portion, an intermediate upwardly and outwardly extending camming portion connecting said upper and lower portions, and a plurality of ears projecting radially outward from said lower annular portion and coinciding in number and circumferential spacing with said body slots, said ears extending into said upper groove of said body when said mandrel is in its unlocked position and into said lower groove of said body when said mandrel is in its locked position;

c. a plurality of locking dogs positioned within said body ports and having outer and inner surfaces, said outer surfaces substantially flush with the outer surface of said body when said mandrel is in its said unlocked position and said inner surfaces are contacting the outer surface of said lower portion of said mandrel, such that when said mandrel is moved axially downward through said body said camming portion bears against said dogs and forces them radially outward through said ports; and

d, at least one inner and one outer annular packing means on said body, said inner packing means around the inner surface of said body and said outer packing means around the outer surface of said body.

16. The underwater well completion apparatus of claim 15 comprising two packoffs mounted one above the other in a unitized wellhead containing a plurality of lateral ports, the lower of said two packoffs forming a seal between said wellhead and a first inner casing string extending into said wellhead, and the upper of said two packoffs forming (1) a seal between said wellhead and a second inner casing string extending into said wellhead, and (2) a seat for a production tubing hanger, each of said packoffs containing at least one lateral passage cooperating with said lateral ports to provide fluid communication between the outer surface of said wellhead and the inner bore of said packoffs.

17. The underwater well completion apparatus of claim 15, wherein said packoff contains at least one lateral passage providing communication between the outside of said packoff and the inner annular bore thereof, such that when said packoff is properly installed in a housing also having at least one cooperating passage and mounted on an outer tubular well string circumscribing an inner tubular well string, the annulus between said well strings is accessible from without said housing by means of said passages.

18. The underwater well completion apparatus of claim 17, wherein said packoff passage extends through said body and said mandrel.

19. The underwater well completion apparatus of claim 17, wherein said packoff passage extends only through said body.