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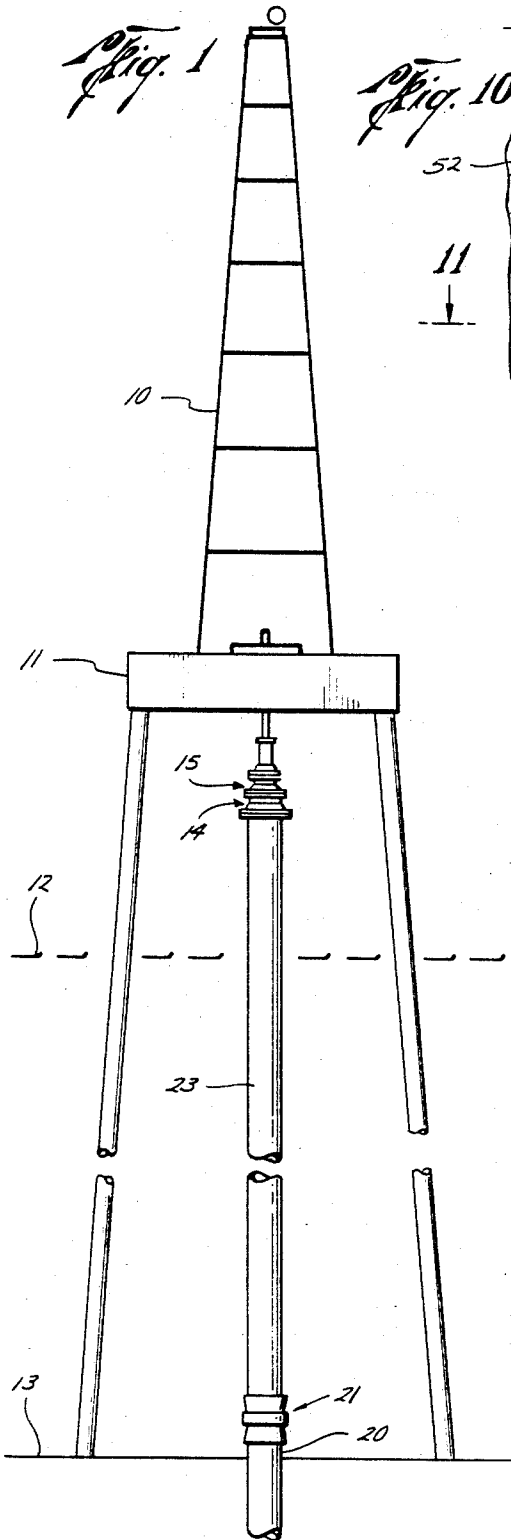
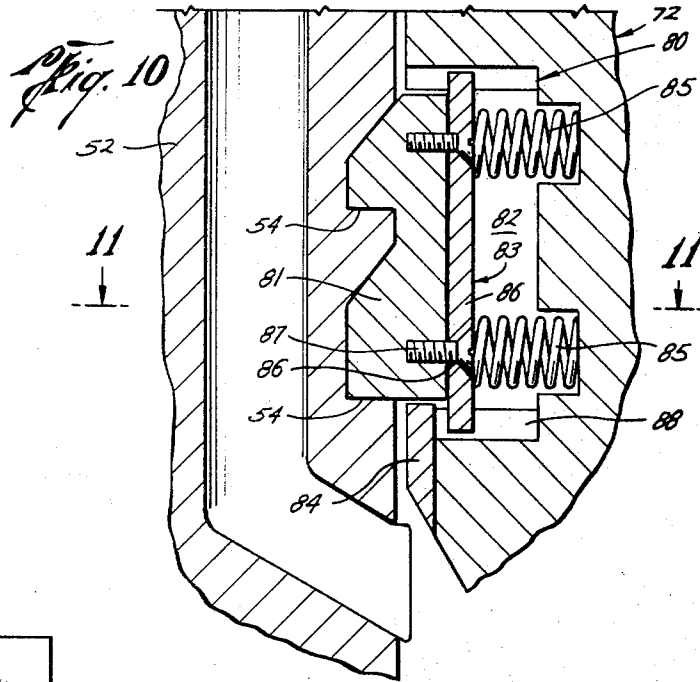
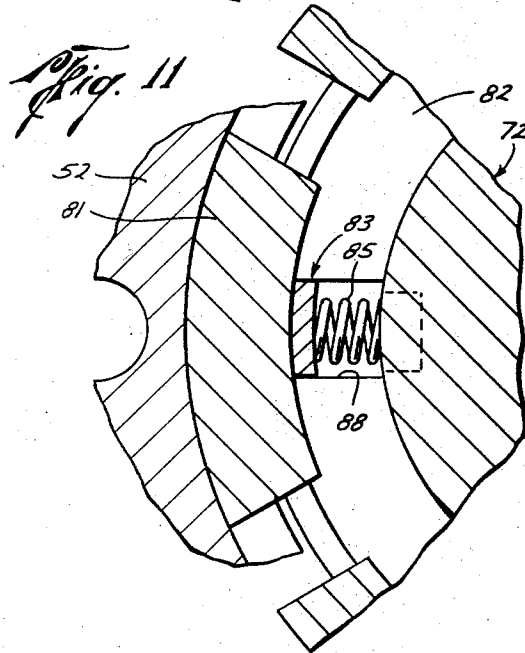
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3,421,580

UNDERWATER WELL COMPLETION METHOD AND APPARATUS

Filed Aug. 15, 1966

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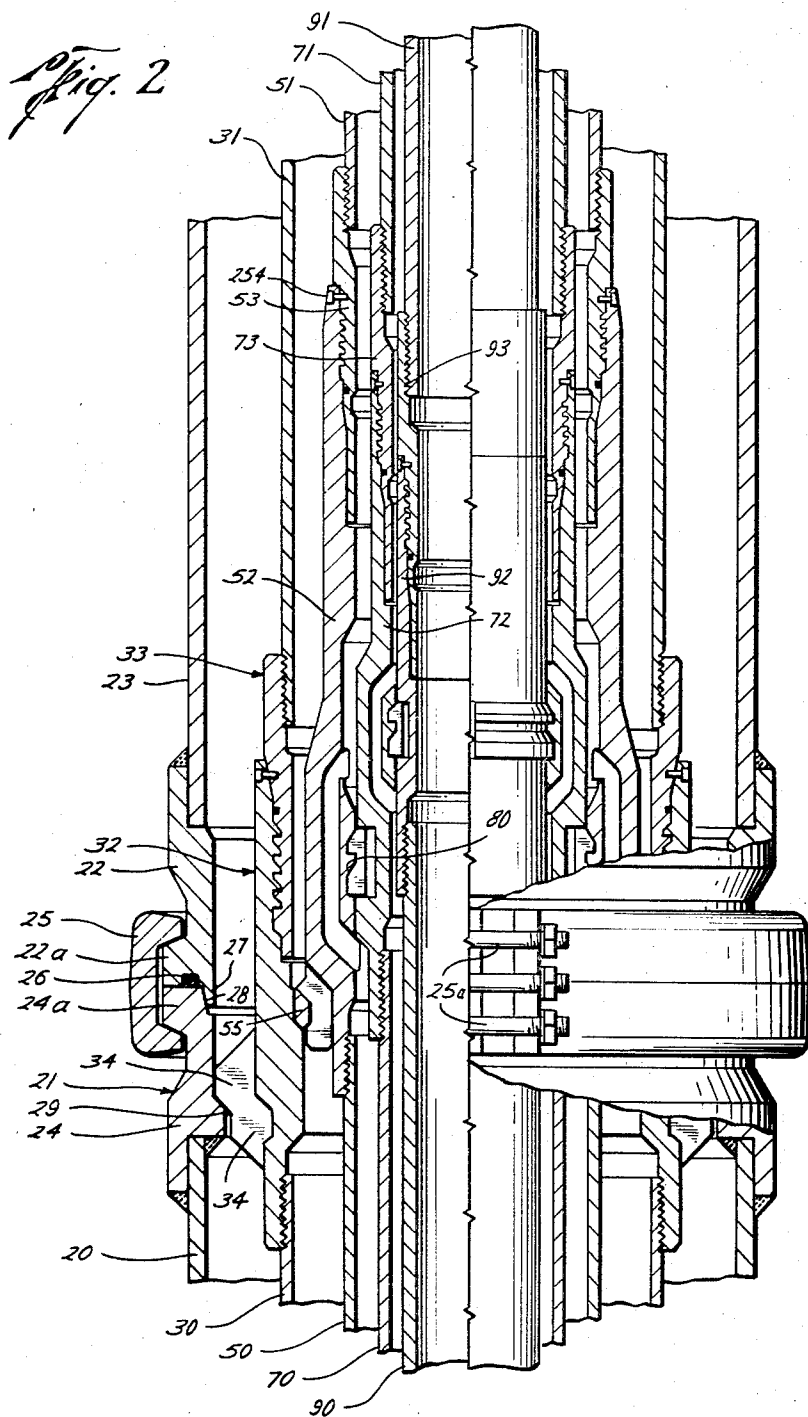
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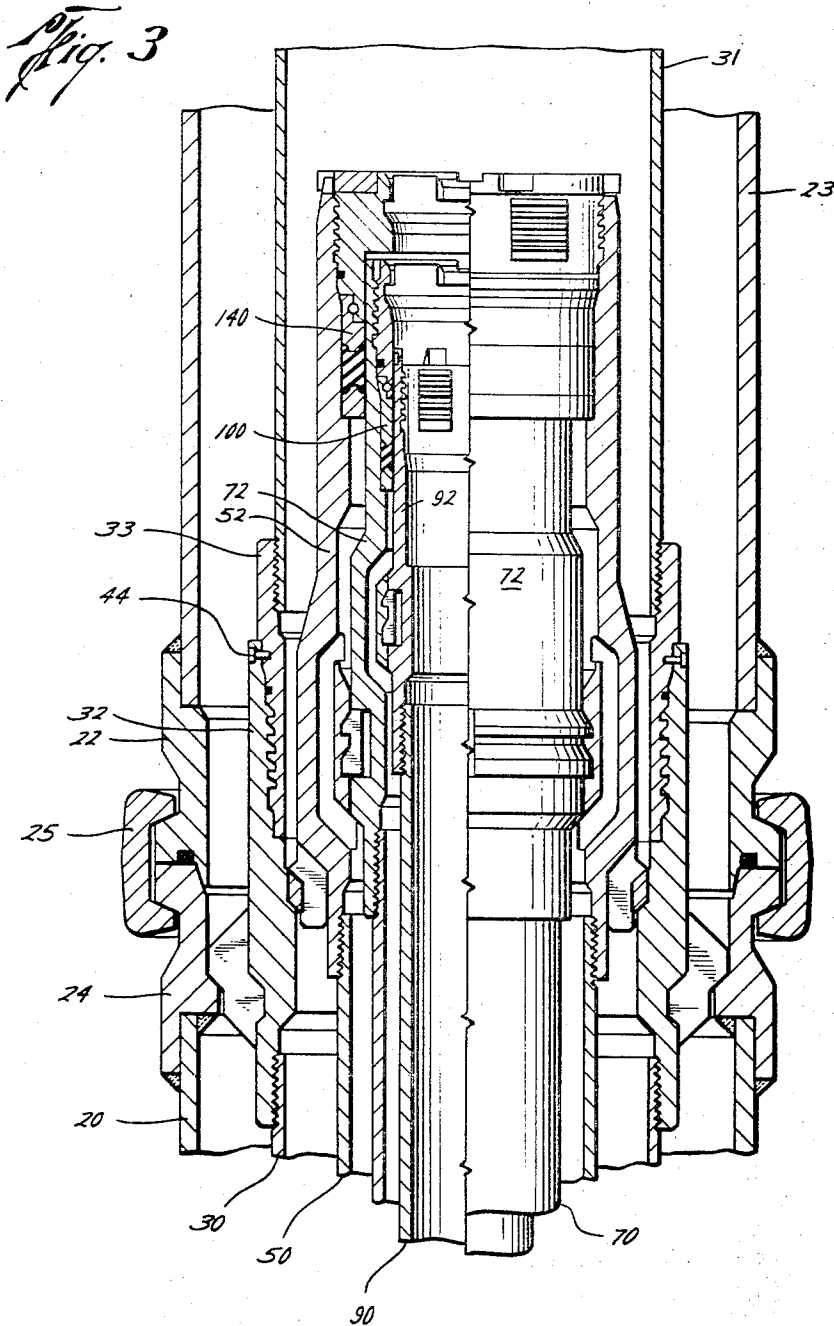
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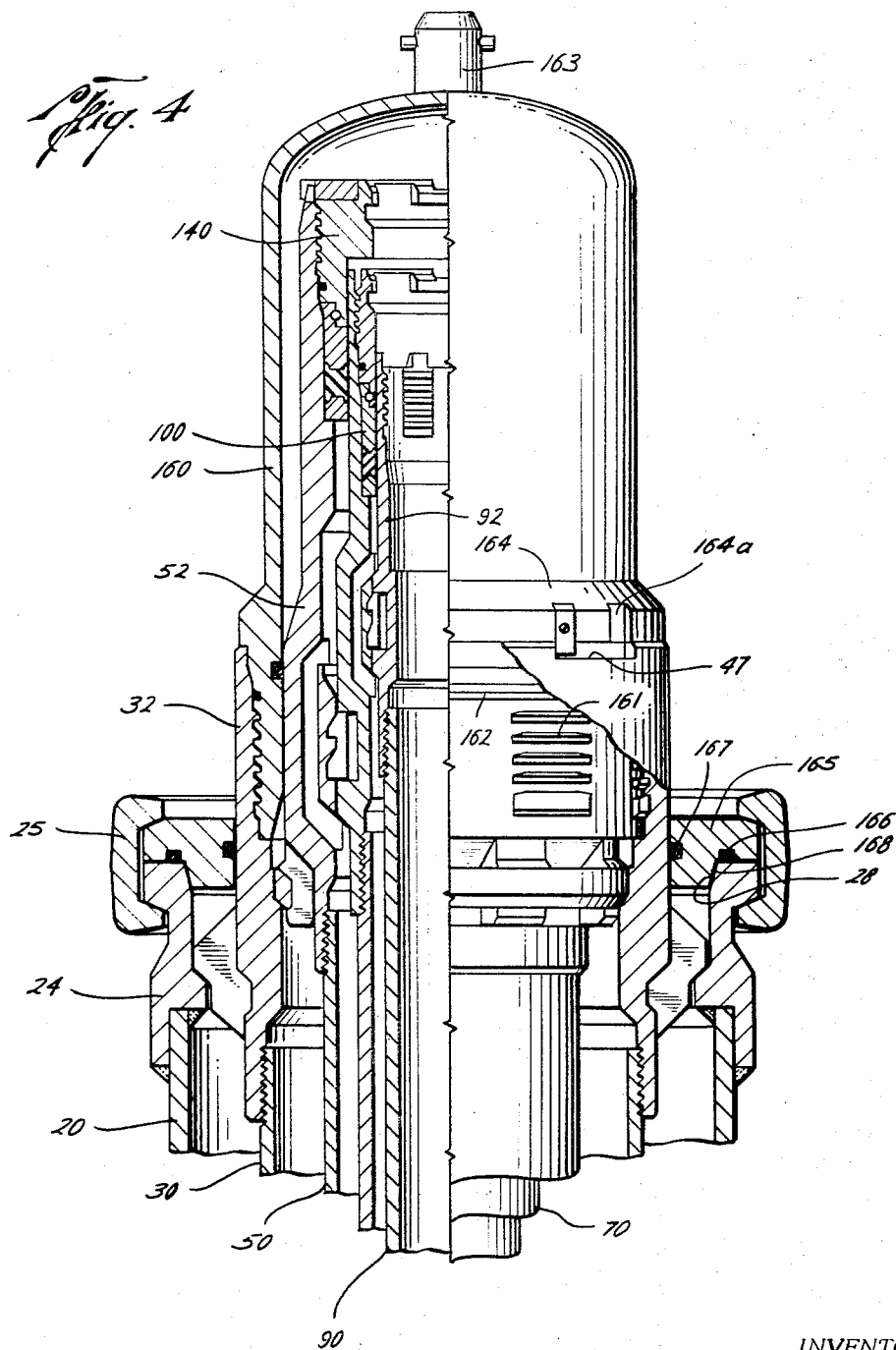
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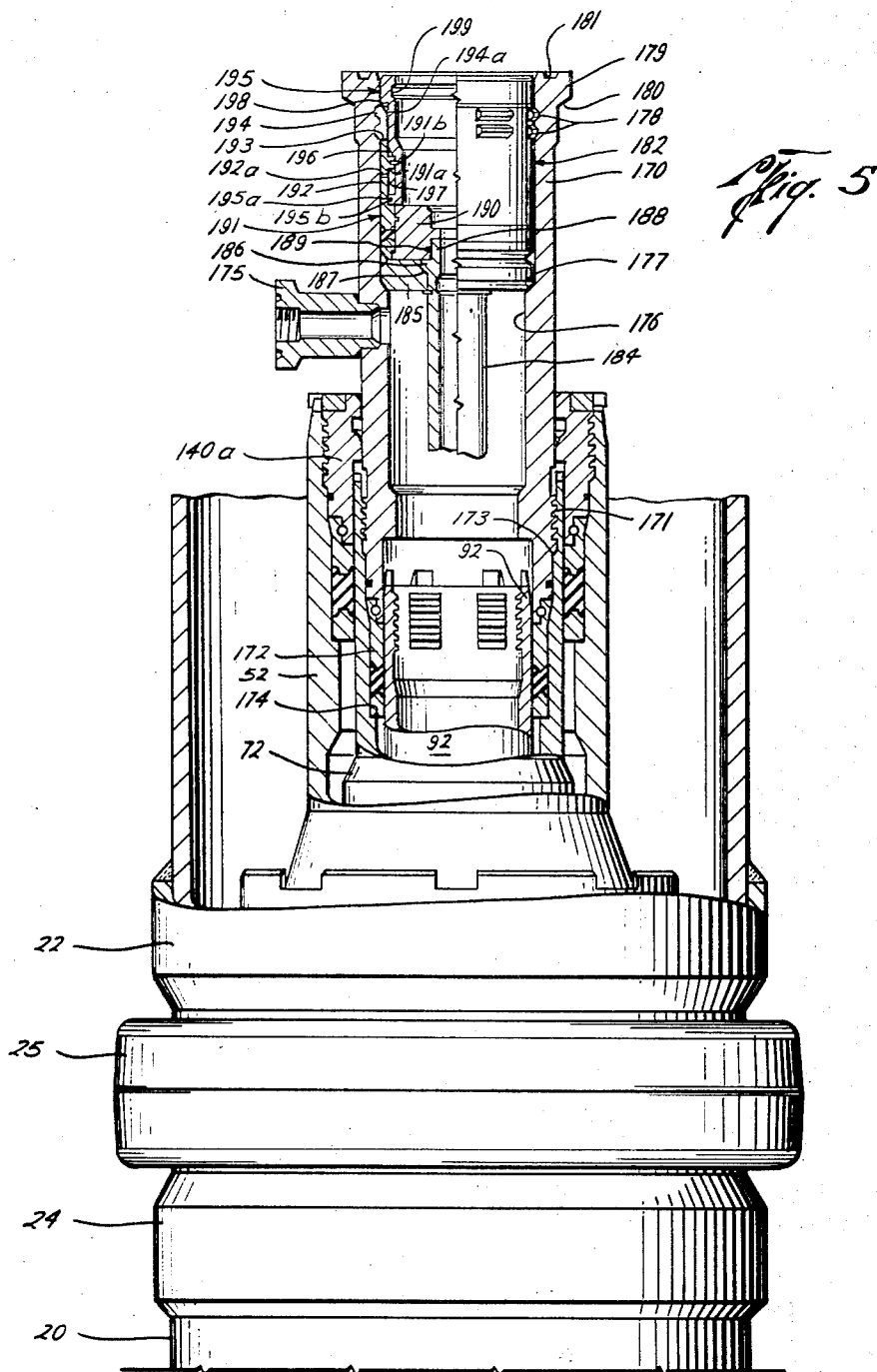
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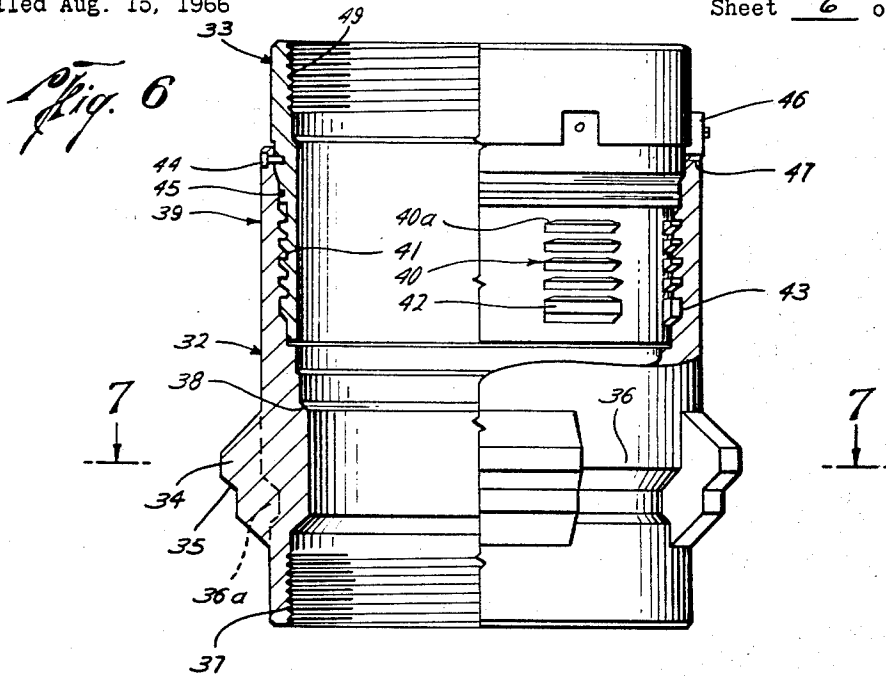
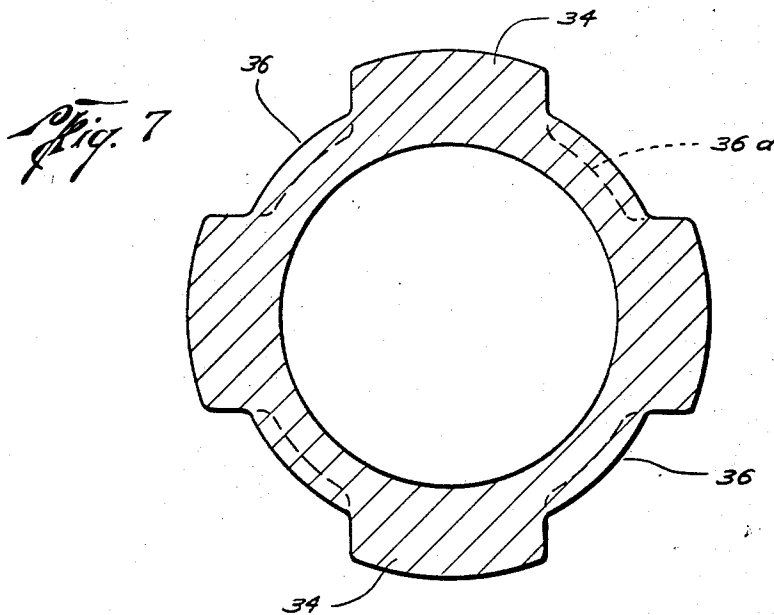
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*Fig. 8*

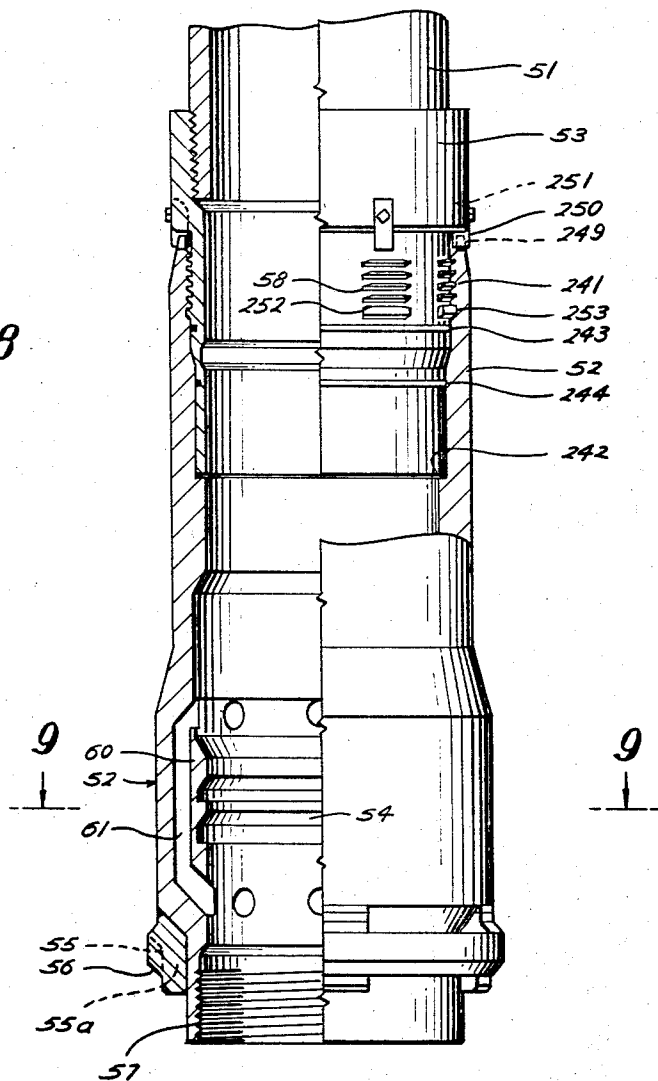
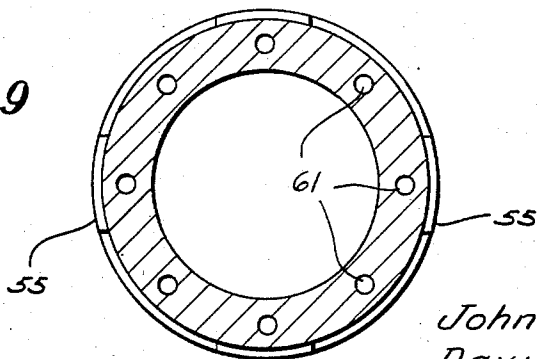


*Fig. 9*



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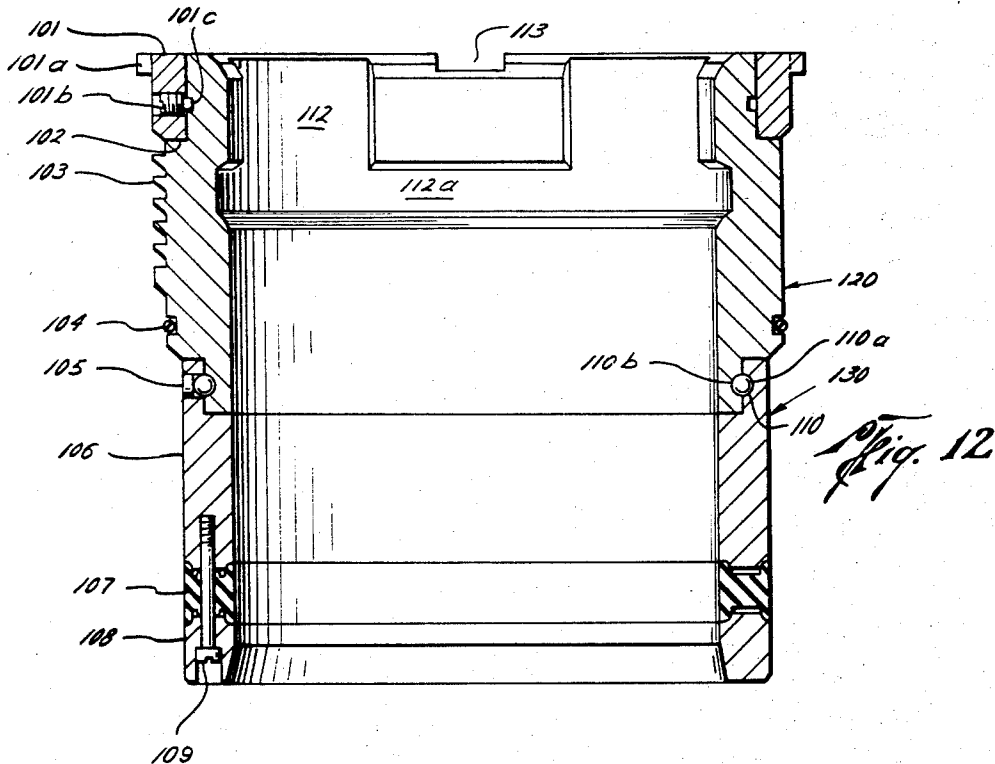
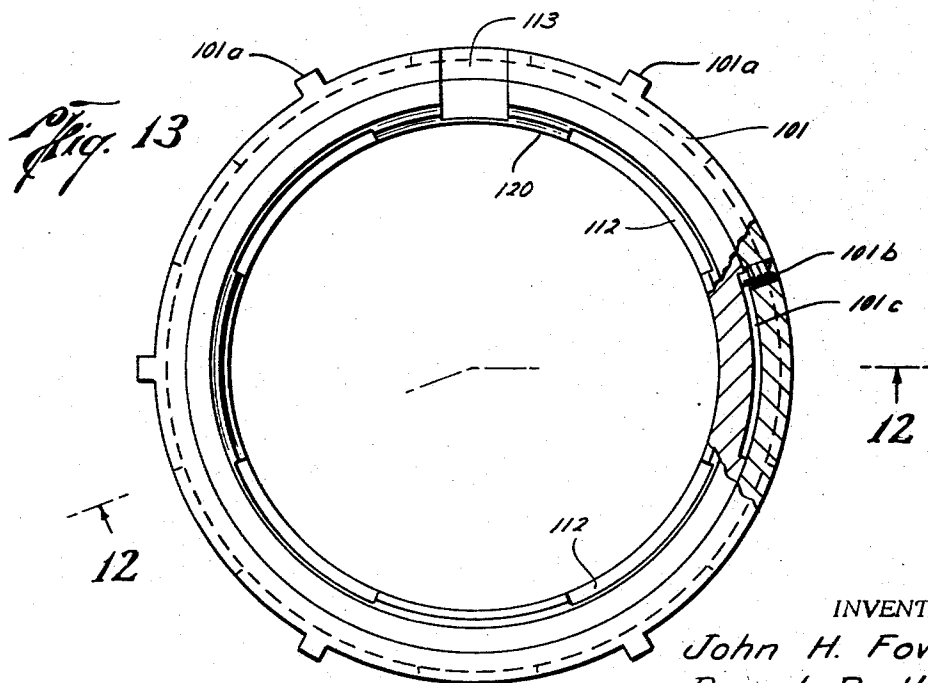
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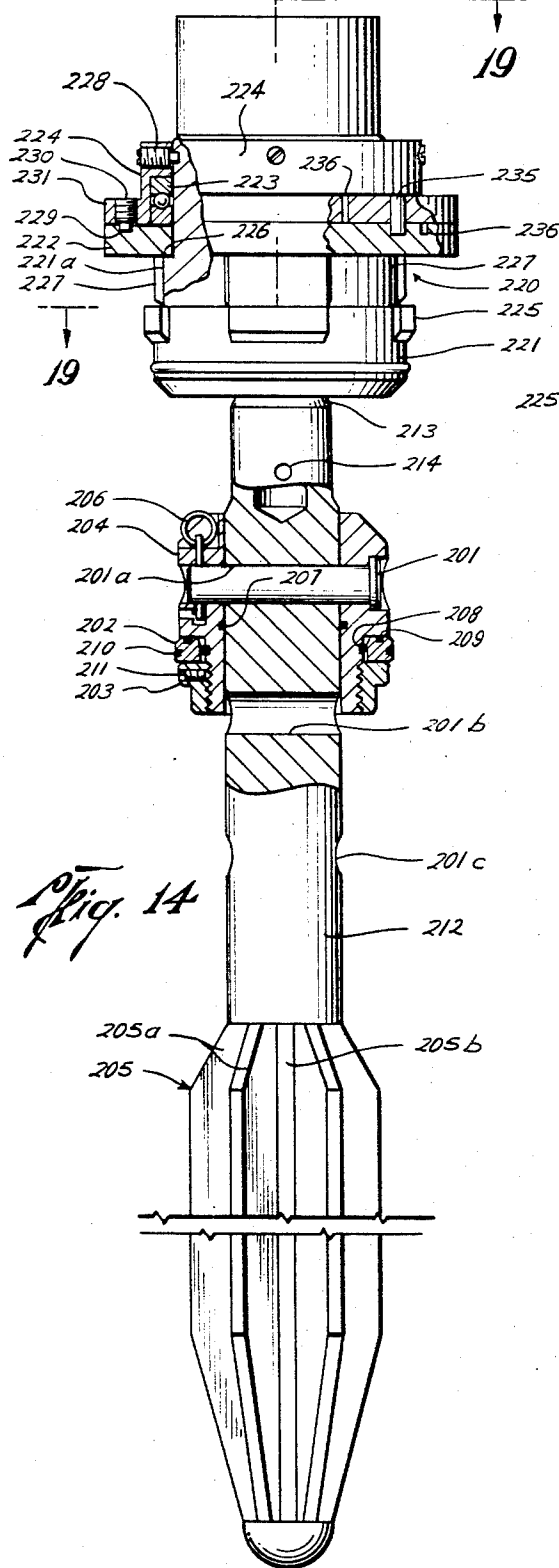
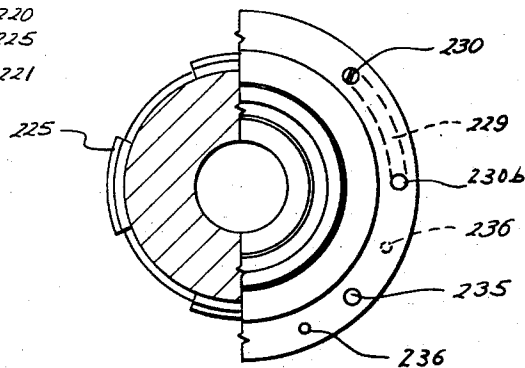
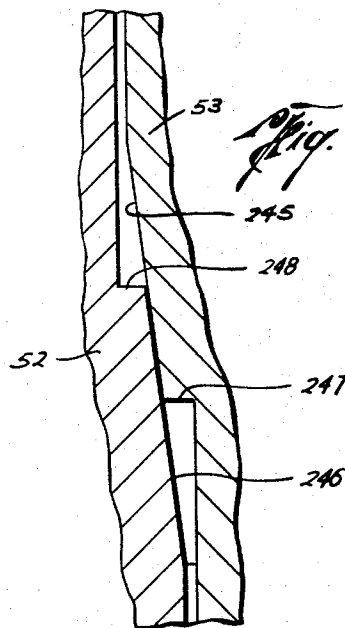
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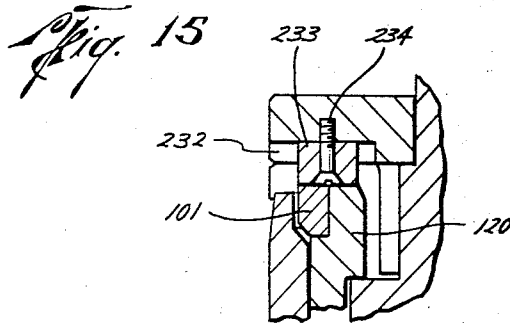
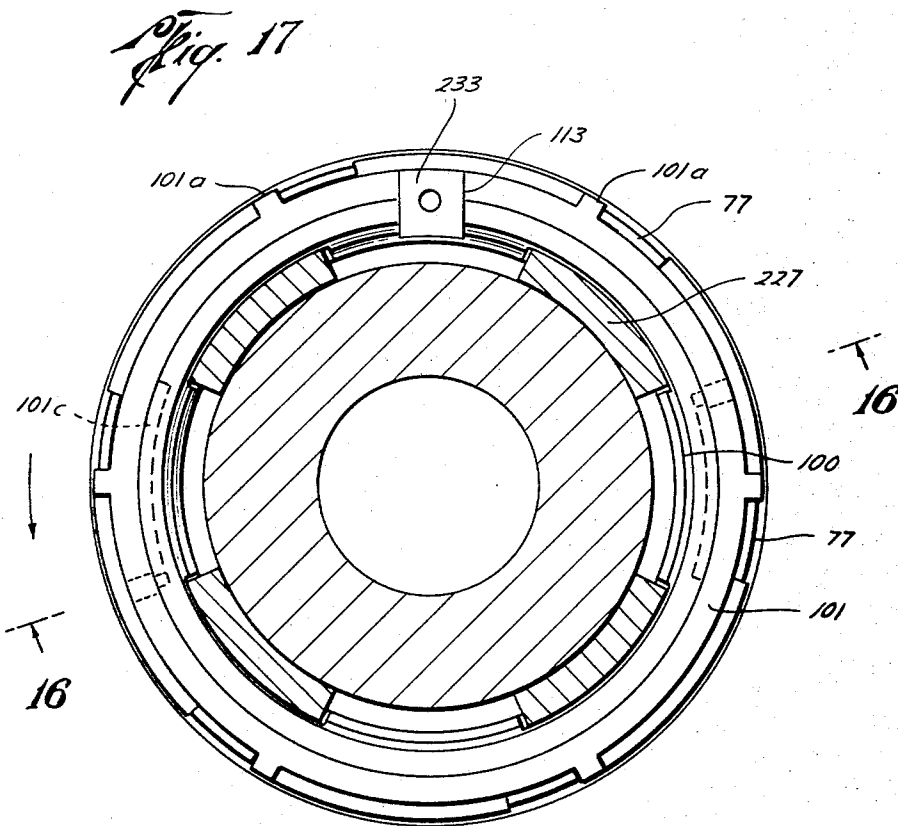
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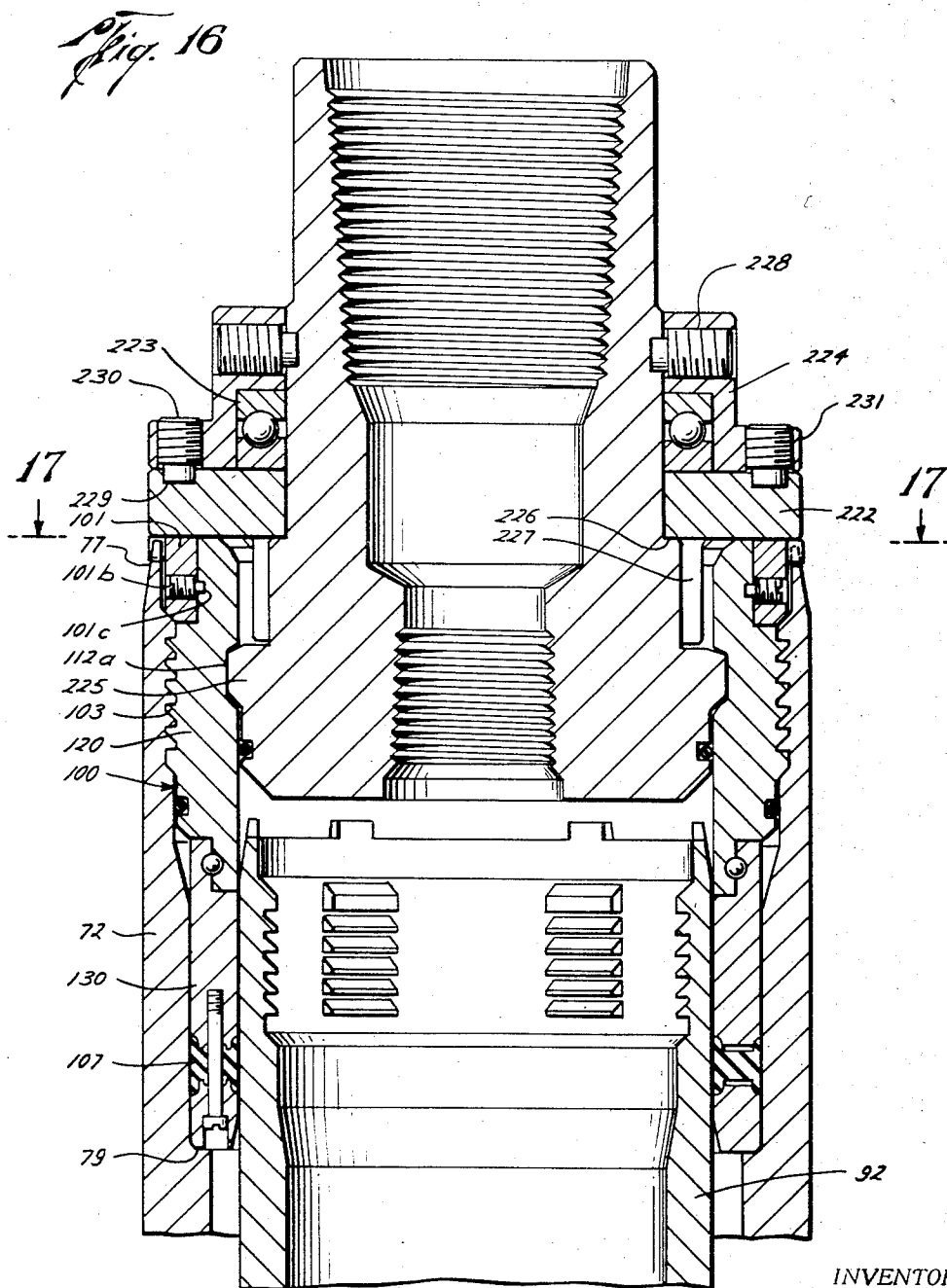
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3,421,580

## UNDERWATER WELL COMPLETION METHOD AND APPARATUS

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U.S. Cl. 166—5

40 Claims

Int. Cl. E21b 33/035; E21b 43/01; E21b 7/12

### ABSTRACT OF THE DISCLOSURE

Method and apparatus for underwater well extended casing completion. The method comprises the steps of installing a conductor pipe with a well head attached above the mudline, attaching a conductor riser to the well head extending to above the water surface, drilling holes for other casings and suspending them with risers attached thereto in the well head by hanger-heads, cementing the other casings in place. At this point the well may be immediately completed by installing an above water production tree or an underwater production tree or temporarily abandoned by packing-off the annular spaces between each hanger-head and capping the well at the well head and later completing above water or underwater, or the well may even be permanently abandoned. Each of the inner casings is supported by a hanger-head which is in turn supported by another hanger-head, the last being supported by the well head. Some of these hanger-heads have ducts through their walls with openings above and below their support surfaces to allow cement fluid returns. The hanger-heads are connected to their respective risers by back-off joints for easy disengagement. One back-off joint disclosed requires only a fraction of a turn for disengagement. Its connection means comprises a plurality of alternating tooth segments and smooth wall segments cooperatively engaging similar segments on its respective hanger-head. When the risers and back-off joints are removed the pack-off may be remotely installed in the annular spaces between adjacent hanger-heads. The pack-off may also utilize the quick connection design of the back-off joint; i.e., the alternating tooth and smooth wall segments. One pack-off embodiment comprises a tubular attachment means and a tubular seal means rotatably attached. The pack-off is inserted in the annular space between hanger-heads. The attachment means is connected through the quick connection tooth segments to one of the hanger-heads. The seal means is compressed sealing the annular space. The pack-offs are removable for replacement of risers, or for other reasons if required.

This invention relates to underwater drilling of oil and gas wells and pertains more particularly to methods and apparatus used in underwater extended casing operations.

Increased activity in offshore drilling has led to continued search for better methods and apparatus in this area. To cope with some of the problems of underwater drilling, various extended casing methods have been developed. Extended casing methods, basically, have a well conductor anchored to the ocean floor which provides support to a special underwater well head. This well head in turn supports a multiple number of hanger-heads, hangers and their respective casing strings. The drilling platform is thus relieved of much of the structural support responsibilities required in other methods. Casing is then extended from the underwater well head to the drilling platform where conventional well head equipment may be used during drilling. After drilling completion, the well may be permanently abandoned, tem-

porarily abandoned or immediately completed for production. If temporarily abandoned, the extended casing may be removed, the exposed casing annuli enclosed in a protective cap and the drilling platform removed. Thus, the underwater well head is free from the hazards of ocean going traffic and structural support problems. A permanent production platform may at some later time be installed, the protective cap removed, casing extended to the permanent platform, and conventional production well head equipment permanently installed.

Of course, if immediate completion is desired it will not be necessary to remove the extended casing and install protective cap, etc.

As can be seen from the foregoing discussion several advantages of the extended casing method of drilling are apparent. However, some problems arise in the use of such methods. Some of these problems are:

- (1) Providing for suspension and pressure loads.
- (2) Providing continuous casing annulus flow for cementing, etc.
- (3) Providing sealing and pack-off means underwater.
- (4) Protecting exposed casing and equipment from underwater environment.
- (5) Providing easy trouble free remote underwater connections.

The present invention attempts to solve these problems.

It is, therefore, a primary object of the invention to provide methods of extended casing completion which may be performed remotely allowing permanent abandonment, temporary abandonment or immediate completion of wells.

Another object of the invention is to provide underwater well head apparatus which may be remotely installed and connected through mechanical means.

A further object of the invention is to provide casing hanger apparatus in well heads which support casing string loads and allow continuous annular flow.

Still another object of the invention is to provide effective pack-off and sealing means for underwater well heads which may be quickly, easily, and remotely installed or removed.

Still another object of the invention is to provide a tool which may be easily adapted to set, test, and remove underwater pack-off and seal means of different sizes.

Still another object of the invention is to provide an underwater well head of the extended casing type which may be adapted to receive extended casing and alternately have such extended casing removed and replaced by pack-off and cap assemblies which protect the well bore from exposure to the underwater environment.

A preferred embodiment of the method and apparatus which are the subject of this invention, and by which the foregoing objects and other objects are attained, is shown in the accompanying drawings and in the following description. As will be seen, the apparatus described embodies versatile structure which is readily used for a variety of purposes. Thus, the hanger-heads which are comprised in the underwater well head of the embodiment disclosed are suitable for supporting casing strings during drilling and cementing operations, and for supporting risers from these casings to the surface of the water. The hanger-heads are also designed to allow fluid flow through the hanger-heads between concentric strings of casing.

A quickly and easily connectable and releasable back-off joint is provided for connection or disconnection of riser casings. The back-off joint connection is also readily adapted to affixing the pack-off in the annulus be-

tween two concentric casing strings. In addition, this same connection provides a highly satisfactory connection for a tubing head.

A pack-off assembly is provided which is easily inserted in the annulus between concentric casing strings, and which is just as easily removed in the event that it is later decided to open such annulus.

The back-off joint in the hanger-head is also suitable for ready connection of a cap in the event that the well is to be capped for temporary abandonment.

Furthermore, a novel tubing head and tubing hanger is provided which is particularly adapted for installation in remote locations.

For a better understanding of the invention, reference is now made to the following description and to the accompanying drawings, wherein

FIGURE 1 is a somewhat schematic elevational view showing a drilling rig and platform in place, with casing and extended casing therebelow, the drilling rig and platform being purposely made small in proportion;

FIGURE 2 is a vertical sectional view of one embodiment of casing support apparatus according to this invention;

FIGURE 3 is a vertical sectional view of one embodiment of casing support apparatus according to this invention, showing the casing packed off;

FIGURE 4 is a vertical sectional view of one embodiment of casing support apparatus according to the invention, showing the well temporarily abandoned;

FIGURE 5 is a vertical sectional view of one embodiment of casing support apparatus according to the invention, showing tubing in place;

FIGURE 6 is half-sectioned elevational view of a hanger-head and back-off joint embodying the invention;

FIGURE 7 is a sectional view of the hanger-head and back-off joint shown in FIGURE 6, taken at line 7—7 of FIGURE 6;

FIGURE 8 is an elevation in partial-section of a hanger-head and back-off joint embodying a modified form of the invention;

FIGURE 9 is a horizontal section taken along line 9—9 of FIGURE 8;

FIGURE 10 is a fragmentary sectional view showing latch means embodied in the invention;

FIGURE 11 is a fragmentary horizontal section taken along line 11—11 in FIGURE 10;

FIGURE 12 is a vertical sectional view of pack-off means embodied in the invention taken at line 12—12 of FIGURE 13;

FIGURE 13 is a top view of the pack-off means of FIGURE 12;

FIGURE 14 is an elevational view, partly in section, of a running tool suitable for setting some of the apparatus of this invention;

FIGURE 15 is a fragmentary sectional view of a portion of the running tool of FIGURE 14, showing it engaged with a pack-off;

FIGURE 16 is a half-section view of a pack-off with a running tool engaged in it, showing the pack-off in position between two hanger-heads;

FIGURE 17 is a horizontal sectional view of the apparatus of FIGURE 16, taken at line 17—17 of FIGURE 16;

FIGURE 18 is a fragmentary sectional view of a portion of the apparatus shown in FIGURE 8; and

FIGURE 19 is a horizontal half-section of the running tool shown in FIGURE 14 taken along line 19—19.

FIGURE 1 of the drawings portrays schematically, in reduced proportion, a drilling rig 10 mounted upon a drilling platform 11 above the water line 12. A conductor riser 23 extends from the above the water line to near the mud line 13 and is surmounted by a landing base 14 which in turn supports conventional casing heads indicated generally at 15. The lower end of the conductor riser 23 is supported on an underwater well head 21, which in turn

is supported on a conductor pipe 20 which comprises surface casing for the well.

For the most part, the apparatus described hereinafter is apparatus which is carried within, comprises a part of, or is immediately adjacent the well head 21. The methods of operation to be described and the apparatus for performing such operations will principally be discussed in terms of the use of a casing program involving a series of five concentric casings which, for the purpose of this discussion, may be described as 30 inch, 20 inch, 13 $\frac{3}{4}$  inch, 9 $\frac{5}{8}$  inch, and 7 inch casings. It will be apparent, however, that the methods and apparatus of this invention may be used equally well with other casing sizes and with different numbers of casings in which the same principles of operation would apply.

The conductor pipe 20 is normally driven or jetted into place, but may be run in a drilled hole if bottom conditions require it. It should be noted that large bending moments may be exerted at approximately the mud line due to water currents, offsets of risers, mud weights, etc. For these reasons, it has been found to be desirable to provide heavier wall pipe beneath the well head 21 for a short distance, such as about 10 feet.

In operation, the 30-inch conductor pipe 20 is installed with the well head 21 and the conductor riser 23 attached thereto. As shown in FIGURE 2 the well head 21 in the embodiment shown consists of an upper hub member 22, which may be welded or otherwise connected to the conductor riser 23, a lower hub member 24 welded or otherwise connected to the conductor pipe 20, and a clamp 25 which connects the hubs 22 and 24 together. The hubs are provided with end flanges 22a and 24a, respectively, which are tapered on the back for engagement by a split clamp 25 which is generally U-shaped in cross-section and has tapered inwardly turned faces proportioned for a tight engagement with the flanges 22a and 24a when they abut each other. The clamp 25 may, for example, be in two semi-circular pieces which are held together as by means of bolts 25a. Seal means are provided between the flanges 22a and 24a as by means of, for example, an O-ring seal 26 and a metal-to-metal seal formed by a tapered extension 27 on the end of flange 22a and a correspondingly tapered bore 28 formed in the end of flange 24a.

An inwardly turned shoulder 29 in the bore of hub 24 comprises an upwardly facing support surface within the well head 21 for supporting other elements as will hereinafter be described.

Following the setting of the 30" conductor casing a hole for 20" surface casing is next drilled and reamed, and the 20" surface casing 30 is run in place, landed, and cemented. Surface casing 30 is suspended in well head 21 on support means 29 by means of support lugs 34 spaced circumferentially around the periphery of a hanger-head 32. Riser 31 is connected to the upper end of hanger-head 32 through back-off joint 33. Riser 31 extends to the surface where it is connected and sealed to a conventional 20" lower casing head, as indicated in FIGURE 1. The lower casing head may serve as a landing base for a conventional 20 $\frac{3}{4}$ " blowout preventer, as is well known in the art. Casing head seal and blowout preventers may be tested at this time.

Referring to FIGURES 6 and 7, hanger-head 32 and back-off joint 33 are shown in detail. Hanger-head 32, conveniently cast in one piece, has a generally cylindrical exterior with a generally cylindrical opening there-through. Near the longitudinal base of its exterior surface, support lugs 34 are radially disposed at regular intervals leaving passage means 36 therebetween. Passage means 36 are enlarged by casting recesses 36a in the wall of hanger-head 32 as shown by phantom lines. A beveled surface 35 is machined on the lower edges of support lugs 34 to cooperate with the beveled shoulder of support means 29 (see FIGURE 2). At the interior base of hanger-head 32 pipe connection means 37 is provided in the form of threads. Near the interior longitudinal center,

support means 38 is provided in the form of a circumferentially beveled shoulder. The inside diameter of hanger-head 32 is enlarged upwardly from support means 38 to allow easy passage of hanger-head 52 which is supported at support means 38 (See FIGURE 2). Breech-locking means 39 is provided at the upper interior of hanger-head 32 and the exterior of back-off joint 33.

The breech-locking means function similarly as a breech-block in, for example, a naval gun. A plurality of longitudinally extending tooth segments 40 are machined on alternate 30-degree segments of the exterior of the back-off joint 33, the arcuate length of the teeth being slightly less than 30 degrees and the upper flanks of all the teeth being beveled at the ends as shown at 40a. Matching tooth segments 41 are machined in the upper interior of hanger-head 32. These teeth also have a length slightly less than 30 degrees. The teeth shown are generally in the form of a buttress thread, but it will be appreciated that other forms can be used. The teeth 41 have, in the embodiment shown, beveled portions at each end on the lower sides of the teeth.

The teeth are engaged with each other by lowering the back-off joint into the hanger-head with the tooth segments 40 positioned to pass between the tooth segments 41. The lowest tooth 42 in the back-off joint has a double thickness, and the lowest groove 43 in the tooth segments 41 has a double width, so that the back-off joint must be lowered far enough to engage the double thickness tooth and the double width groove. The back-off joint may then be rotated 30 degrees to engage the breech-locking means. The teeth do not have any lead angle, but they are pulled tightly into engagement by means of the bevels 40a on the ends of the teeth 40 and the corresponding bevels on the ends of the teeth 41.

Sealing is obtained between the back-off joint and the hanger-head by means of an O-ring 45 positioned around the back-off joint just above the tooth segments 40. In order to prevent the back-off joint and hanger-head slipping with relation to each other during the time they are being lowered into the well, they are held together by means of a shear pin 44.

If, after the hanger-head 32 with its associated casings having been positioned in the well, it is desired to remove the back-off joint 33, this may be done simply by twisting the riser casing 31 to the right. This twisting force to the right will shear the shear pin 44 and movement of the back-off joint 30 degrees will disengage the teeth 40 from the teeth 41. Rotation of the back-off joint with relations to the hanger-head is stopped after 30 degrees by means of a stop comprising a key 46 mounted in a milled slot on the back-off joint 33 in such a way as to contact the end of a key slot 47 on the upper end of the hanger-head 32.

Female threads 49 in the upper end of the back-off joint provide means for connection to the riser casing 31.

Referring now to FIGURE 2 again, after the 20" casing has been set, a hole is drilled for 13 $\frac{3}{8}$ " casing 50, and the casing is run, landed and cemented in a conventional manner. Hanger-head 52, back-off joint 53, and riser 51 are shown made up in their proper places. The 13 $\frac{3}{8}$ " riser 51 is extended to the surface and packed off in a conventional manner (not shown). The 20 $\frac{1}{4}$ " preventer is removed, 13 $\frac{3}{8}$ " x 20" surface pack-off installed, a conventional intermediate casing head installed, and pack-off tested. 12" preventers are then installed and tested.

Referring now to FIGURES 8 and 9 hanger-head 52 is shown in detail. Hanger-head 52 is generally cylindrical on its exterior and has a generally cylindrical opening therethrough. The center portion of hanger-head 52 has an outside diameter substantially greater than the end portions. This results in a thicker wall to allow for integral passage means 61 in the form of ducts. These ducts 61 are circumferentially disposed and extend longitudinally through the wall as shown in FIGURES 8 and

9 to allow passage of fluid around another hanger-head 72 (to be described later) which is suspended on the interior wall of hanger-head 52 (see FIGURE 2). The interior wall near the center of hanger-head 52 is provided with latch support means 54 in the form of two circumferentially machined grooves which will cooperate with latch means 80 (to be explained later) to support hanger 72 and its attached casing 70 (see FIGURE 2).

At the exterior base of the larger diameter center portion of hanger-head 52 support ring 55 is welded. At regular intervals circumferentially disposed passage means 55a are provided between the ring 55 and the body of the hanger-head 52. Support ring 55 has a beveled downwardly facing surface 56 on its outer edge which is proportioned to engage support means 38 on the interior of hanger-head 32 (see FIGURE 2). This allows passage of fluid between hanger-head 32 and hanger-head 52. At the interior base of hanger-head 52 pipe connection means 57 are provided in the form of threads for engagement with cooperating threads on the upper end of casing 50.

At the upper interior of hanger-head 52 tooth segments 58 are provided to cooperate with tooth segments on the exterior of back-off joint 53 to provide breech-locking means which in many respects is similar to the breech-locking means of hanger-head 32.

However, this breech-locking means is useful for several different functions, and therefore comprises some features not found in the breech-locking means of hanger-head 32.

FIGURE 8 shows hanger-head 52 with back-off joint 53 installed therein and with riser 51 threaded into the back-off joint. As shown, a plurality of longitudinally extending tooth segments 240 are machined on alternate 30-degree segments of the exterior of the back-off joint 53, the arcuate length of the teeth being slightly less than 30 degrees. The upper flanks of the teeth in tooth segment 240 are beveled at the ends similarly as the teeth in the tooth segments 40 previously described. The lowest tooth 252 is approximately twice as thick as the others. Matching tooth segments 241 are machined in the upper interior of the hanger-head 52, with the lowest groove 253 twice as wide as the others for engagement by double-thickness tooth 252. These teeth also have an arcuate length slightly less than 30 degrees and have the beveled portions on the lower flanks of the teeth at each end. The teeth shown are generally in the form of buttress threads, but it will be appreciated that other forms of teeth can be used.

Spaced substantially below the tooth segment 241, the hanger-head 52 has an inwardly turned support shoulder 242. Intermediate the support shoulder 242 and the tooth segments 241, the back-off joint 53 sealingly engages the hanger-head. The sealing means includes two O-ring seals 243 and 244 which are positioned in suitable grooves around the circumference of the back-off joint below the teeth 240 of the back-off joint. Intermediate the O-rings 243 and 244, the back-off joint is tapered, as shown in FIGURE 18 at 245, to engage a cooperating taper 246 formed in the bore of the hanger-head 52. A run-out groove 247 is provided at the small end of taper 245 and a similar run-out groove 248 is provided at the large end of taper 246.

The upper end of the hanger-head 52 is provided with a plurality, preferably six, stops 249, positioned for engagement by keys 250 which are positioned in slots 251 milled in the outer edge of the back-off joint and which extend downwardly therefrom far enough to fit between the stops 249.

The back-off joint will normally be assembled in the hanger-head at the surface before lowering into the well. This is accomplished by merely inserting the back-off joint into the hanger-head with the tooth segments 240 aligned with the spaces between the tooth segments 241 and moving the two members together until the large

double thickness tooth 252 is positioned opposite the double width groove 253. At this point, the tapered surfaces 245 and 246 will be substantially in engagement. The back-off joint may then be rotated 30 degrees to the right to engage the tooth segments 240 with the tooth segments 241. The beveled top flanks of the teeth of segment 240 engage the beveled bottom flanks of the teeth of segment 241 to cause the back-off joint to be pulled down further into the hanger-head so as to force tapers 245 and 246 into sealing engagement with each other as the back-off joint is rotated into position. A shear pin 254 (see FIGURE 2) is then inserted to hold the relationship of the back-off joint and the hanger-head. The elements may then be lowered into the well.

When it is desired to separate the back-off joint from the hanger-head, it is merely necessary to apply a right-hand twisting force to the casing riser 51 so that the shear pin 254 is sheared. The back-off joint will then rotate 30 degrees until it is stopped by the engagement of the key 250 with the stop 249. The back-off joint may then be removed by merely lifting straight up.

Referring again to FIGURE 2, when the 13 $\frac{3}{8}$ " casing is in place, a hole for the 9 $\frac{5}{8}$ " casing 70 is drilled. The 9 $\frac{5}{8}$ " casing string 70 is run in the hole with hanger-head 72, back-off joint 73, and riser 71 properly made up. The casing string 70 is then cemented in a conventional manner. The riser 71 is extended to the surface where the 12" preventer is removed and 9 $\frac{5}{8}$ " x 12" surface packing installed. A conventional intermediate well head is installed and tested. A 10" preventer is next installed and tested.

Hanger-head 72 is similar to hanger-head 52 of FIGURE 8 except that the function of support ring 55 of hanger-head 52 is performed by latch means 80, which can best be described with reference to FIGURES 10 and 11. Latch means 80 basically consists of latch segments 81, segment groove 82, guide means 83, retainer ring 84, and spring means 85. Latch segments 81 are conveniently made by machining a ring whose profile is that shown in FIGURE 10; then cutting the ring into four segments slightly less than 90 degrees each. The segments are mounted in segment groove 82 which is circumferentially machined on the exterior of hanger-head 72. Guide means 83 consists of a vertical bar 86 attached to the inner face of latch segments 81 by screws 87. The ends of vertical bar 86 ride in guide channels 88 which are radially machined on the top and bottom of latch groove 82 at 90 degree intervals. Latch segments 81 are forced radially outward by spring means 85. The configuration of the latch segments is such that they will not be forced out into any recess above the hanger-head 52.

Upon downward movement of hanger-head 72 within hanger-head 52 latch segments 81 automatically engage support means 54 to support suspension load.

To disengage latch means 80, hanger-head 72 is simply moved upwardly, causing the latch segments 81 to move radially inwardly due to the cooperating beveled upper surfaces of the latch segments 81 and support means 54. The lower ends of vertical bars 86 engage retainer ring 84 to prevent the latch segments from being forced out of segment groove 82 by the springs 85.

Back-off joint 73 is similar in construction to back-off joint 53, except that it is dimensioned smaller.

In the next step, referring again to FIGURE 2, a hole is drilled for 7" inner casing 90. The casing 90 is then made up with hanger-head 92 and back-off joint 93 in their proper places. Riser 91 is extended to the surface. Cementing is then completed normally. Hanger-head 92 is similar to hanger-head 72 except that no integral passage means are required since this is the last casing string. Back-off joint 93 is similar to back-off joints 53 and 73 as previously described.

At this stage of procedure several alternatives are possible. The well may be immediately completed, temporarily abandoned, or permanently abandoned.

If the well is to be immediately completed the next step is to remove, at the surface, the 10" preventers, install a 7" x 10" surface pack-off, install a 10" x 6" tubing head equipped with 7" bottom pack-off and test. A 6" preventer would then be installed and tested, casing perforated, tubing run, pack-off installed and back pressure valves installed. The preventer would then be removed, a production tree installed and tested, and the well brought in. All of these procedures and equipment are conventional and, therefore, need no description.

However, if the well is to be temporarily abandoned, in the next step all perforations will be squeezed off and one or more bridge plugs run, set and tested in the 7" casing in a conventional manner. The 6" preventer 10" x 6" tubing head and 7" x 10" surface pack-off will be removed. The 7" riser 91 and back-off joint 93 will then be rotated approximately 30 degrees clockwise, shearing a shear pin such as shear pin 44 as shown in FIGURE 6. Rotation is limited to 30 degrees by stop means such as 46 and 47 in FIGURE 6. Thus, the breech-locking means is disengaged and 7" casing 91 may be elevated and removed along with back-off joint 93. Again at the surface the 12" x 10" intermediate casing head and 9 $\frac{5}{8}$ " x 12" surface pack-off is removed. As previously described for 7" riser 91, the 9 $\frac{5}{8}$ " riser 71 is rotated 30 degrees clockwise and removed along with back-off joint 73.

At this point, a 7" x 9 $\frac{5}{8}$ " pack-off means 100 will be run. The pack-off means is run by attaching it to a suitable tool 200 at the surface and lowering it on a pipe string to engage the breech-locking means in hanger-head 72 as hereinafter described and as shown in FIGURE 3.

Referring to FIGURES 12 and 13, pack-off means 100 will be described in detail. Pack-off means 100 consists basically of two major assemblies, an upper section 120 which locks and holds the pack-off down, and a lower section 130 which contains the sealing element. These two sections can rotate in relation to each other.

Upper section 120 is generally cylindrical in shape. On its exterior, alternate rows of tooth segments 103 and smooth wall segments are machined at 30 degree intervals. Tooth segments 103 are similar to tooth segments 58 on back-off joint 53 in FIGURE 8, and therefore require no additional description. On the upper exterior of upper section 120 a circumferentially extending shoulder 102 is provided on which ring 101 sits. Ring 101 is annular in shape and has six lugs 101a extending radially outwardly at 60 degree intervals. It is held to upper section 120 by two oppositely disposed pins 101b, which are inserted through pack-off ring 101, the end of which rides in arcuate slots 101c machined in 30 degrees of the exterior circumference of upper section 120. The interior of upper section 120 is provided with longitudinally extending 45 degree tool slots 112 intersecting an annular tool groove 112a, which provides J slot engagement for running tool 200 to be described later. Secondary seal means 104 in the form of an O-ring is mounted in a groove near the exterior base of upper section 120. Slot 113 is machined on the upper edges of upper section 120 and ring 101 to provide for a key on the running tool, to be explained later.

Lower section 130 consists of upper cylindrical retainer ring 106, lower cylindrical retainer ring 108, primary seal means 107 therebetween, and connection means comprising cap screws 109 whose heads are counter-sunk in the lower end of ring 108. Seal 107 is made of a resilient material such as rubber, and is adapted to seal on both its inner and outer circumferences when compressed between retainer rings 106 and 108.

Referring now to FIGURES 14 and 19, the pack-off running and pulling tool 200 will be described. It has three major assemblies, guide means 205, plug means 204 and engaging means 220.

Guide means 205 has steel ribs 205a extending radially from a shaft 205b so that the outside diameter of the

rib edges is slightly less than the inside diameter of the innermost hanger-head 92 (see FIGURE 3). Guide means 205 on entering hanger-head 92 aligns the tool 200 and pack-off means 100 vertically and horizontally. At the upper end of tool shaft 212, connection means in the form of threads 213 is provided. A test port 214 is drilled radially through the shaft to communicate with a hollow portion 214a of the tool, the bore of engaging means 220, and the pipe string to which tool 200 is connected.

Near the middle of tool 200 is a plug means 204 which is cylindrical in shape, its outside diameter being such as to fit with a slight clearance in the inside diameter of the upper portion of hanger-head 92. An O-ring 207 seals between the plug 204 and the tool shaft 212. Mounted at the base of plug means 204 is a seal means consisting of a floating ring 202, a retainer ring 203 and O-rings 208, 209, and 210. This type design will provide effective sealing even if slight eccentricity of hanger-head equipment exists, since O-ring 208 allows the ring 202 to "float" within certain tolerances. Ring 202 is held on plug means 204 by lower retainer ring 203 which is threaded to run on a lower threaded portion of plug means 204. Set screw 211 holds retainer ring 203 in place. Plug means 204 is mounted on the tool shaft 212 by a pin 201 which is inserted in a hole 201a passing through plug means 204 and tool shaft 212. Pin 201 is held in place by lock pin 206. Several additional holes 201b and 201c are provided at different locations on the tool shaft so that plug means 204 may be maintained at the same relative position in hanger-head 92 regardless of which pack-off means is being installed.

Engaging means 220 has a body section 221, slip ring 222, bearing means 223 and cap means 224. The base of body section 221 has a diameter to fit within the smallest diameter of pack-off means with which the tool will be used. Near the base of body section 221 four equally spaced 45 degree lugs 225 are provided which project outwardly to a diameter slightly less than that of the tool groove 112a in the pack-off means. The diameter of body section 221 in the spaces between lugs 225 is the same as the base diameter. Just above the lugs 225 the diameter of the body section is reduced at 221a. At a point above lugs 225 a shoulder 226 is provided by further reducing the diameter of body section 221. Slip ring 222 which rests on this shoulder 226 has four 45 degree fingers 227 projecting downwardly at intervals of 90 degrees to a point slightly above lugs 225. Bearing means 223 rests on slip ring 222. Cap means 224 which rides on the upper edge of bearing means 223 is attached to body section 221 by pins 228, thereby holding bearing means 223 in place. Two 45 degree arcuate slots 229 are cut on the upper surface of slip ring 222 at 180 degree intervals. Dog point set screws 230 are inserted in the lower flanged portion 231 of cap means 224 at fixed positions so that the ends of the set screws 230 may ride in slots 229. Slot 232 (see FIGURE 15) is milled on the lower edge of slip ring 222 to provide for key 233 attached to slip ring 222 by screw 234. Key 233 will also fit into slot 113 machined on the top of pack-off means 100 (see FIGURE 12).

Referring now to FIGURES 16 and 17 in setting a pack-off, tool 200 would be inserted in pack-off means 100 with lugs 225 being in tool groove 112a on pack-off means 100. Fingers 227 are inserted in tool slots 112 (see FIGURE 12) 45 degrees out of phase with lugs 225. A shear pin 235 (see FIGURE 14) holds body section 221 and slip ring 222 in this position so that the tool lugs 225 remain engaged with tool groove 112a. Key 234 is inserted so that slip ring 222, pack-off ring 101 and upper section 120 of pack-off means 100 may not rotate relative to each other. Set screws 230 are inserted so that they rest at the counter-clockwise ends, viewed from the top, of slots 229. The tool and attached pack-off are lowered into the well bore. The lower tooth of the pack-off tooth segments 103 will probably come to rest on the

upper tooth of hanger-head 72 tooth segments. The tool and pack-off are then rotated until the pack-off tooth segments line up with hanger-head 72 smooth segment portions at which time the pack-off drops into the hanger-head. At this point lower section 130 of the pack-off means 100 contacts shoulder 79 in hanger-head 72, compressing seal means 107 and sealing the annular space between hanger-heads 72 and 92. Tool 200 and the upper section 120 of pack-off 100 are now rotated clockwise 30 degrees causing the full engagement of the breech-locking means. At this point the lugs 101a on ring 101 have contacted the lugs 77 on hanger-head means 72.

To remove the tool, the pipe string holding it is again twisted to the right until shear pin 235 is sheared, allowing body section 221 to rotate relatively to pack-off means 100. Rotation is limited to 45 degrees by set screws 230 coming to a stop at the clockwise end of slots 229. At this point lugs 225 are now aligned with tool slots 112 on pack-off means 100 and the tool may be removed by simply pulling upwardly.

To remove pack-off means 100, the lugs 225 on body section 221 and fingers 227 of slip ring 222 are first vertically aligned. A shear pin is inserted in holes 236 through cap 224 into slip ring 222 to hold this position. Set screws 230 are inserted so that they rest at the clockwise end of slot 229. Key 233 is removed. The tool 200 is now lowered into the well bore into contact with the upper end of the pack-off and rotated until lugs 225 and fingers 227 are aligned with tool slots 112 in the pack-off 100, causing the tool to drop to the lower shoulder of tool slots 112. Sufficient clockwise torque is applied to shear the shear pin in hole 236, and the body section 221 is then rotated clockwise. Rotation is limited to 45 degrees by set screws 230 coming to a stop against the clockwise end of slots 229. At this point lugs 225 have fully engaged tool groove 112a on the interior of pack-off means 100. On further rotation tool 200 and upper section 120 of pack-off means 100 move together for 30 degrees, being stopped by the end of slot 101c on upper section 120 coming to rest against pin 101b on ring 101. At this point the breech-locking means is disengaged and pack-off means 100 may be pulled upwardly.

In the next step in preparing the well for temporary abandonment, the 13 $\frac{3}{8}$ " riser 51 and back-off joint 53 are removed by first shearing a shear pin similar to shear pin 44, then rotating 30 degrees clockwise to release the breech-locking means. After these are removed, pack-off means 140 is run in the annular space between hanger-head 52 and hanger-head 72 in the same manner as described for pack-off means 100. Pack-off means 100 and 140 are similar to each other, the primary difference being only in diameters. However, the inside diameter in upper section which receives the running tool may be the same so that one running tool may be used for different size pack-off units. At this point, the structure is as shown in FIGURE 3.

Next, the 20" riser 31 and back-off joint 33 are removed by rotating 30 degrees clockwise, shearing the shear pin 44 and releasing the breech-locking means as previously described.

A well cap 160, as shown in FIGURE 4, is then attached to the hanger-head 32 by means of the breech-locking means. As shown in FIGURE 4, the well cap 160 comprises a substantially tubular member having an upper closed end to which a back pressure valve 163 is attached. Such back pressure valves, which comprise a kind of check valve adapted to be opened by a plunger from above, are well known in the art and need not be described further here. The lower end of the cap is provided with tooth segments 161 corresponding to the tooth segments 40 on back-off joint 33 and therefore engageable with the tooth segments 41 of the hanger-head 32. An O-ring seal 162 around the well cap just above the tooth segments 161 sealingly engages the bore of hanger-head 32 to provide a pressure tight joint when the well

cap is fully engaged. Rotation of the well cap to the proper point of engagement of the cooperating teeth is assured by the stop slots 47 in the upper edge of the hanger-head 32 which are engaged by keys 164 disposed around the circumference of the well cap and extending downwardly therefrom. A milled slot 164a above the other end of slots 47 allows the insertion of an additional key by a diver to prevent the cap from accidentally rotating.

The cap 160 now serves as a protective housing for the underwater well head apparatus and well bore. Fresh water may be circulated in the well bore until clear returns are received and lubricating oil may be pumped in to displace the water in the well head. Back-pressure valve 163 serves as a means of checking pressure before re-entry.

The next step comprises removing the conductor riser 23 with its hub 22. This is done by sending a diver down to remove the bolts 25a holding clamp 25. When the conductor riser has been lifted clear, the diver drops into place the annular seal ring 164, which is of substantially the same diameter and external configuration as the flange 22a of the hub 22. An O-ring seal member 166 is provided between the face of member 165 and the end of flange 24a, and an O-ring 167 is provided between the member 165 and the hanger-head 32. A metal-to-metal seal is also afforded by the tapered extension 168 which fits within the tapered bevel 28 in the flange 24a. Following the insertion of the seal member 165, the diver replaces the clamp 25. He may at this time also attach the additional keys in slots 164a. The well is now entirely closed in and is ready for temporary abandonment.

When recompletion of the well is desired, the flexibility of this system offers two options, in that the well may be recompleted on bottom or at the surface.

If recompleted on bottom, an underwater tubing head 170 as shown in FIGURE 5 replaces pack-off means 100. At the same time, pack-off 140 is pulled and replaced by pack-off 140a which has a large enough bore to clear the tubing head 170. It will be apparent that a different running tool diameter will be required to set pack-off 140a.

Underwater tubing head 170 is secured to hanger-head 72 by the breech-locking means previously described. Tooth segments 171, similar to the tooth segments on pack-off 100, are machined near the exterior lower end of tubing head 170. At the base and below the tooth segments of tubing head 170, a sealing section 172, similar to lower section 130 of pack-off means 100 (see FIGURE 12), is telescopically and rotatably attached by ball bearings as in pack-off means 100.

To install tubing head 170, it is lowered into position and rotated until the tooth segments line up with smooth segment portions on hanger-head 72. It is then pushed downwardly until the bottom tooth on its tooth segments contacts a shoulder 173 in hanger-head 72. As this is done the sealing section will also be seated on a lower shoulder 174 in hanger-head 72 and will be compressed, sealing the annulus between hanger-heads 72 and 92. Tubing head 170 is then rotated 30 degrees causing full engagement of the breech-locking means.

The upper portion of the tubing head may be of conventional structure, however, a novel structure having particular advantages for remote underwater installations is shown in FIGURE 5. The tubing head there shown is of generally tubular configuration and has a conventional side outlet 175 in communication with the annulus between the tubing and the casing. The outlet 175 communicates with a bore 176 which terminates above the outlet 175 in an upwardly facing beveled support shoulder 177. The enlarged bore above the support shoulder 177 terminates at the top of the tubing head and has a straight smooth wall except where interrupted by a pair of circumferentially extending recesses 178 near the upper end of the bore.

The exterior of the upper end of the tubing head may

be formed for any conventional connection to a Christmas tree or other well head elements but a preferred form, as shown in the drawing, comprises a flange 179 having a beveled back 180 suitable for use in a clamped connection similar to that formed by clamp 25 as shown in FIGURE 2. A conventional ring groove 181 may be formed in the face of flange 179 for a sealing connection to another well head element.

The drawing shows a tubing hanger 182 suitable for supporting a single string of tubing. It will be appreciated, however, that hangers adapted for supporting multiple strings of tubing might also be used.

The tubing hanger assembly shown has novel features which make it peculiarly suitable for use in remote underwater installations. The tubing (not shown) is connected by the usual threaded connection into a coupling 184 which is supported on an annular hanger ring 185 by the resting of a collar 186 on an upwardly facing support shoulder 187 in the hanger ring. The hanger ring in turn rests upon the support shoulder 177 of the tubing head. An upper extension 188 of the coupling is sealingly engaged as by means of an O-ring 189 in a pack-off adapter ring 190. The pack-off adapter ring has an annular clearance between it and the surrounding tubing head and a sandwich pack-off 191 is inserted between the pack-off ring and the tubing head. This sandwich pack-off structure may be generally similar to pack-off 130 as shown in FIGURE 12. The upper end of the pack-off comprises a tubular portion 192 which has a sliding fit in the tubing head and which is provided with a plurality of circumferentially distributed windows 193 through its walls through which latch segment elements 194 are slidably received.

A latching sleeve 195 is telescopically received within the tubular portion 192 of the pack-off and holds the latches 194 in place. The latching sleeve is provided with a beveled surface 196 which prior to engagement of the latches 194 is positioned in contact with the beveled surfaces 194a on the latches. The latching sleeve has an annular recess 197 immediately adjacent the beveled surface 196 to receive the latches 194 prior to the movement of the latches into the latch recesses 178 and the tubing head. Thus, it will be appreciated that to install the pack-off a handling tool engages the groove 199 in the upper end of the latching sleeve and lowers the entire assembly into the tubing head. At this time the latches 194 are retracted into the annular groove 197 and the pack-off is supported on the latching sleeve by means of cooperating opposed collars 191a and 195a. This position is temporarily maintained by shear pins passing through holes 192a in tubular portion 192 and holes 195b in collar 195a. When the pack-off has been positioned above the annulus between the ring 190 and the bore of the tubing head, the latching sleeve is pushed downwardly, after shearing the aforementioned shear pins, to force the pack-off into the annulus and to force the latches 194 into the latch grooves 178. To prevent latching sleeve 195 from being inadvertently displaced a spring biased shear pin 191b in collar 191a is forced into a hole in latch sleeve 195. The pack-off is thus latched into place and is held down by the latches 194.

To release and remove the pack-off, pin 191b is sheared by pulling upwardly on latch sleeve 195. This allows, on further upward motion of latch sleeve 195, latches 194 to spring out of engagement. The pack-off may then be removed, cooperating collars 191a and 195a resting against each other and transmitting upward force to the pack-off.

If, instead of completing at the bottom, the well is to be recompleted at the surface, the well cap 160 will be removed, first testing for pressure in the well through back-pressure valve 163. All risers and back-off joints will be replaced as pack-off means are removed. The reverse procedure as for abandonment is followed. A standard well head is used at the surface except that no casing hangers but only pack-offs, are required in it. If desired

only some of the strings may be re-connected. This may require a special pack-off means to replace a standard one to allow for passage of casing.

If the well is to be permanently abandoned, substantially the same procedure will be followed as in temporary abandonment. However, no pack-off means will be installed and before removing the conductor riser all casings will be plugged and cut or blown off below the mudline. The conductor riser may then be removed having the well head and all hanger-heads attached thereto. This allows recovery of all apparatus in the underwater well head.

While preferred embodiments of the invention have been shown and described, many modifications thereof can be made by one skilled in the art without departing from the spirit of the invention and it is intended to protect by Letters Patent all forms of the invention falling within the scope of the following claims.

We claim:

1. A method of completing an underwater well comprising the steps of
  - locating drilling means at an underwater well site,
  - installing conductor pipe with a well head attached above the mudline,
  - attaching to said well head a conductor riser extending above the water surface with landing base being attached thereto,
  - drilling holes for other casings,
  - suspending said other casings with risers attached thereto in said well head by hanger-heads,
  - cementing said other casings in place by circulating through said other risers and casings and through integral passage means in said hanger-heads,
  - testing the well,
  - removing said other risers,
  - installing pack-off means in the annular spaces between said hanger-heads,
  - removing said conductor riser and landing base,
  - attaching a well cap to said well head, and
  - temporarily abandoning said well.
2. The combination of claim 1 and including the steps
  - removing said well cap,
  - reinstalling said conductor riser and landing base attached thereto,
  - removing said pack-off means,
  - reinstalling said other risers,
  - installing casing head and control equipment,
  - installing a tubing head and a surface pack-off,
  - running tubing,
  - installing surface production tree, and
  - bringing in said well.
3. The combination of claim 1 including the steps of
  - removing said well cap,
  - installing an underwater tubing head,
  - running tubing and pack-off,
  - installing an underwater production tree, and
  - bringing in said well.
4. Well completion apparatus comprising
  - a conductor pipe,
  - underwater well head means connected to said conductor pipe,
  - hanger-head means concentrically positioned in and supported by said well head means,
  - other casing means suspended from said hanger-head means, and
  - pack-off means installed in annular spaces between said hanger-head means removable from said spaces on rotating less than one revolution relative to said hanger-head means.
5. The combination of claim 4 in which at least one of said hanger-head means is solely supported on the surrounding hanger-head means by latch means on the exterior thereof,
  - said latch means having a plurality of latch segments

radially movable in a circumferential segment groove,

the outer face of said latch segment being correlatively shaped to engage cooperating support surfaces on the interior of said surrounding hanger-head means, and

means resiliently urging said latch segments into engagement with said cooperating support surfaces.

6. Well completion apparatus comprising
  - a conductor pipe,
  - underwater well head means connected to said conductor pipe,
  - hanger-head means concentrically positioned in and supported by said well head means,
  - other casing means suspended from said hanger-head means, and
  - pack-off means installed in annular spaces between said hanger-head means
  - at least one of said hanger-head means having fluid passage means integrally disposed in the wall thereof,
  - said fluid passage means terminating in upper and lower openings on the interior of said one hanger-head means,
  - support means being provided on the interior wall of said one hanger-head means between said upper and lower openings to support another hanger-head means concentrically therewithin.

7. A method of completing an underwater well comprising the steps of
  - locating drilling means at an underwater well site,
  - installing conductor pipe with a well head attached above the mudline,
  - attaching to said well head a conductor riser extending above the water surface with landing base being attached thereto,
  - drilling holes for other casings,
  - suspending said other casings with other risers attached thereto in said well head by hanger-heads,
  - cementing said other casings in place by circulating through said other risers and casings and through integral passage means in said hanger-heads,
  - testing the well,
  - removing said other risers,
  - installing pack-off means in the annular spaces between said hanger-heads,
  - installing underwater tubing head,
  - running tubing and pack-off,
  - removing said conductor riser and attached landing base,
  - installing underwater production tree, and
  - bringing in the well.

8. Well completion apparatus comprising
  - a conductor pipe,
  - underwater well head means connected to said conductor pipe,
  - a plurality of hanger-heads concentrically positioned in and supported by said well head means with annular spaces therebetween,
  - other casing means suspended from each of said hanger-heads,
  - underwater tubing head means connected in one of said annular spaces between said hanger heads,
  - pack-off means installed in the other annular spaces between said hanger-heads,
  - tubing suspended from said underwater tubing head means, and
  - production tree means connected to said tubing head.
9. The combination of claim 8 in which
  - at least one of said hanger-heads has a latch means on the exterior thereof,
  - said latch means having a plurality of latch segments radially movable in a circumferential segment groove,
  - the outer face of said latch segments being correlatively shaped to engage cooperating support surfaces on the interior of a surrounding hanger-head,

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and means resiliently urging said latch segments into engagement with said cooperating support surfaces.

10. Well completion apparatus comprising first generally tubular hanger-head means, second generally tubular hanger-head means concentrically disposed within said first hanger-head means with an annular space therebetween, and a tubing head supported on said first hanger-head means by a releasable connection and having a portion sealingly received between said hanger-head means.

11. Well completion apparatus as defined by claim 10 wherein said releasable connection by which said tubing head is supported on said first hanger-head means comprises a breech-block connection.

12. Well completion apparatus as defined by claim 10 wherein said first hanger-head means has an upwardly facing internal shoulder, said portion of said tubing head has a longitudinally compressible tubular packoff, and said packoff engages said shoulder and is compressible between said shoulder and said releasable connection.

13. Well completion apparatus as defined by claim 10 and including a metal-to-metal seal connection between said tubing head and said first hanger-head means which comprises an external taper on said tubing head, and a corresponding internal taper in said first hanger-head means, said tapers being sealingly engaged by the engagement of said releasable connection.

14. Well completion apparatus comprising a conductor pipe, an underwater well head connected to said conductor pipe, a conductor riser connected to said underwater well head, a landing base connected to the upper end of said conductor riser above the water surface, a hanger-head concentrically positioned in and supported by said well head, another casing suspended from said hanger-head, a releasable back-off connected to said hanger-head, and another riser connected to said hanger-head, said other riser extending above the water surface.

15. The combination of claim 14 in which said hanger-head and said back-off are connected by a breech-block connection.

16. The combination of claim 14 in which said hanger-head and said back-off are connected by a breech-block, said breech-block comprising circumferentially disposed tooth segment means on the interior of said hanger-head and corresponding circumferentially disposed tooth segment means on the exterior of said back-off, said tooth segment means being alternate rows of no lead angle teeth and smooth wall portions, and cooperating stops on said hanger-head and said back-off to limit their relative rotation.

17. The combination of claim 14 in which said hanger-head has a fluid passage integrally disposed in the walls thereof, said fluid passage terminating in upper and lower openings on the interior of said hanger-head, and support means provided on the interior walls of said hanger-head between said upper and lower openings adapted to support another hanger-head concentrically therewithin.

18. The combination of claim 17 and including another concentrically disposed hanger-head supported on said support means, and in which said other hanger-head has a latch means on the exterior thereof, said latch means having a plurality of latch segments

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radially movable in a circumferential segment groove, the outer face of said latch segments being correlatively shaped to match the surfaces of said support means on the interior of the surrounding hanger-head,

and means resiliently urging said latch segments into engagement with said support means.

19. Pipe suspension apparatus comprising tubular hanger-head means, pipe connection means at the lower end of said hanger-head means, support means on the exterior of said hanger-head means for supporting it on a surrounding element, means for allowing fluid flow from below said hanger-head means to above it, and a sealing breech-block connection at the upper end of said hanger-head means, said breech block connecting comprising circumferentially disposed tooth segment means on the interior of said hanger-head, said tooth segment means being alternate rows of no lead angle teeth and smooth wall portions.

20. The combination of claim 19 and including tubular back-off means, said back-off means being attached to said hanger-head means by corresponding rows of no lead angle teeth on its exterior engaging said hanger-head means teeth, said back-off means and hanger-head means being disengageable on rotation of said back-off means no more than one-half of a revolution, and pipe connections means on the upper interior of said back-off means.

21. Pipe suspension apparatus comprising tubular hanger-head means, pipe connection means at the lower end of said hanger-head means, support means on the exterior of said hanger-head means for supporting it on a surrounding element, means for allowing fluid flow from below said hanger-head means to above it, tubular back-off means attached to said hanger-head means by a breech-block connection, said breech-block connection being held in full engagement by shear means, including interchangeable key and stop means on said back-off means, and positioned to allow relative rotation of said back-off means and said hanger-head means from engaged position to disengaged position upon shearing of said shear means.

22. The combination of claim 21 and including a tapered surface on the exterior of said back-off means below said breech-block connection, a cooperating tapered surface on the interior of said hanger-head means to form primary metal-to-metal seal means, and an O-ring seal between said back-off means and said hanger-head means adjacent said primary seal means.

23. Pipe suspension apparatus as defined by claim 19 and including support means on the interior of said hanger-head means, and fluid passage means formed in the wall of the hanger-head means with openings into the interior thereof above and below said interior support means.

24. The combination of claim 23, and including tubular back-off means, said back-off means being attached to said hanger-head means by said breech-block connection, and pipe connection means in the form of threads on the upper interior of said back-off means.

25. The combination of claim 24 in which said breech-block connection is held in full engagement by shear means, and including interengageable key and stop means on said

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back-off means and said hanger-head means positioned to allow relative rotation of said back-off means and said hanger-head means from engaged position to disengaged position upon shearing of said shear means.

26. The combination of claim 25 and including a tapered surface on the exterior of said back-off means below the breech-block connection, and a cooperating tapered surface on the interior of said hanger-head means to form a primary metal-to-metal seal means, and an O-ring seal between said back-off means and said hanger-head means adjacent said primary seal means.
27. Pipe suspension apparatus as defined by claim 19 wherein said support means comprises radially extensible latch means.
28. The combination of claim 27 and including passage means integrally disposed in the walls of said hanger-head, said passage means having upper and lower openings on the interior of said hanger-head means, latch support means on the interior of said hanger-head means located between said upper and lower openings of said passage means.
29. The combination of claim 27 and including tubular back-off means, said back-off means being attached to said hanger-head means by said breech-block connection, and pipe connection means in the form of threads on the upper interior of said back-off means.
30. The combination of claim 29 and including a tapered surface on the exterior of said back-off means below said breech-block connection, and a cooperating tapered surface on the interior of said hanger-head means to form primary metal-to-metal seal means, and an O-ring seal between said back-off means and said hanger-head means adjacent said primary seal means.
31. A hanger-head for supporting a pipe in a well having a generally tubular shape, fluid passage means integrally disposed in the walls thereof, said fluid passage means having upper and lower openings into the interior of said hanger-head means, and pipe support means on the interior of said hanger-head means, said support means being between said upper and lower openings.
32. The combination of claim 31 in which tooth segment means are circumferentially disposed on the upper interior of said hanger-head means, said tooth segment means being in the form of alternate longitudinal rows of teeth and smooth surface segments, said teeth having no lead angle.
33. The combination of claim 32 and including tubular back-off means, releasably attached to said hanger-head means by breech-locking means, said breech-locking means being the combination of said tooth segment means in the upper interior of said hanger-head means and correlative tooth segment means on the exterior of said back-off means, and pipe connection means being located on the upper interior of said back-off means.
34. First tubular hanger-head means, said hanger-head means having fluid passage means integrally disposed in the walls thereof, said fluid passage means having upper and lower openings into the interior of said hanger-head means, and latch support means on the interior of said hanger-head means, said openings being located above and below said latch support means,

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said latch support means being in the form of at least one groove circumferentially formed on the interior wall of said first hanger-head means, the bore of said hanger-head means being substantially straight except for said latch support means, and second tubular hanger-head means with latch means on the exterior of said second hanger-head means engaged with said latch support means.

35. The combination of claim 34 in which said latch means are a plurality of latch segments radially movable in a circumferential segment groove on said second hanger-head means, the outer face of said latch segments being correlatively shaped to match the surfaces of said latch support means on the interior of said first hanger-head means, and means resiliently urging said latch segments into engagement with the latch support means.

36. Well apparatus comprising, first tubular hanger-head means, first support means on the interior of said first hanger-head means, second tubular hanger-head means concentrically disposed within said first hanger-head means, said second hanger-head means having second support means on the exterior thereof cooperating with said first support means on the interior of said first hanger-head means, fluid passage means between the first and second hanger-head means including an annular space at the upper end thereof, pack-off means installed in said annular space, said pack-off means having attachment means thereon to connect it to one of said hanger-head means, and seal means rotatably connected to said attachment means, said pack-off means sealing said annular space between said first and second hanger-head means.

37. A well pack-off means comprising attachment means for releasably attaching said pack-off means to a surrounding support member, and tubular seal means rotatably attached to the base of said attachment means.

38. A well pack-off means as defined by claim 37, wherein

said attachment means comprises circumferentially disposed longitudinal rows of arcuate teeth of no lead angle with smooth surface arcs between the rows.

39. A well pack-off means as defined by claim 37, and including

a tapered portion on said attachment means adapted to engage a corresponding tapered portion on a surrounding element to form a metal-to-metal seal.

40. A well head means comprising upper hub means, said upper hub means being generally cylindrical with a cylindrical passage therethrough and having a flange portion at its base, lower hub means being generally cylindrical and having a cylindrical passage therethrough, said lower hub means having a flange portion at its upper end, clamp means engaged with and holding together said flange portions of said upper and lower hub means, support means on the interior of said lower hub means, first seal means of the metal-to-metal type comprising a beveled shoulder on the upper interior of said lower hub means and a downwardly tapered conical lip at the base of said upper hub means, said beveled shoulder and said tapered conical lip being in full circumferential contact, second seal means of the resilient type between said flanges, and pipe connection means at the base of said lower hub means and the upper end of said upper hub means.

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