United States Patent

Bauer et al.

[15] **3,682,243**

[45] **Aug. 8, 1972**

[54] **UNDER WATER WELLS**

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[73] Assignee: **Shell Oil Company**, Los Angeles, Calif.

[22] Filed: **Oct. 7, 1968**

[21] Appl. No.: **765,565**

Related U.S. Application Data

[60] Division of Ser. No. 675,714, Aug. 1, 1957, which is a continuation-in-part of Ser. No. 468,214, Nov. 12, 1954, Pat. No. 2,808,229.

[52] **U.S. Cl.** **166/0.6**, 175/7

[51] **Int. Cl.** **E21b 7/12**

[58] **Field of Search** 166/0.5, 0.6; 175/5–10; 251/1

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Primary Examiner—Marvin A. Champion
Assistant Examiner—Richard E. Favreau
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[57] **ABSTRACT**

Underwater wells are drilled with equipment which can be guided from a floating vessel to an underwater well and locked in place to facilitate moving equipment to and from the well during drilling and completion operations.

7 Claims, 12 Drawing Figures

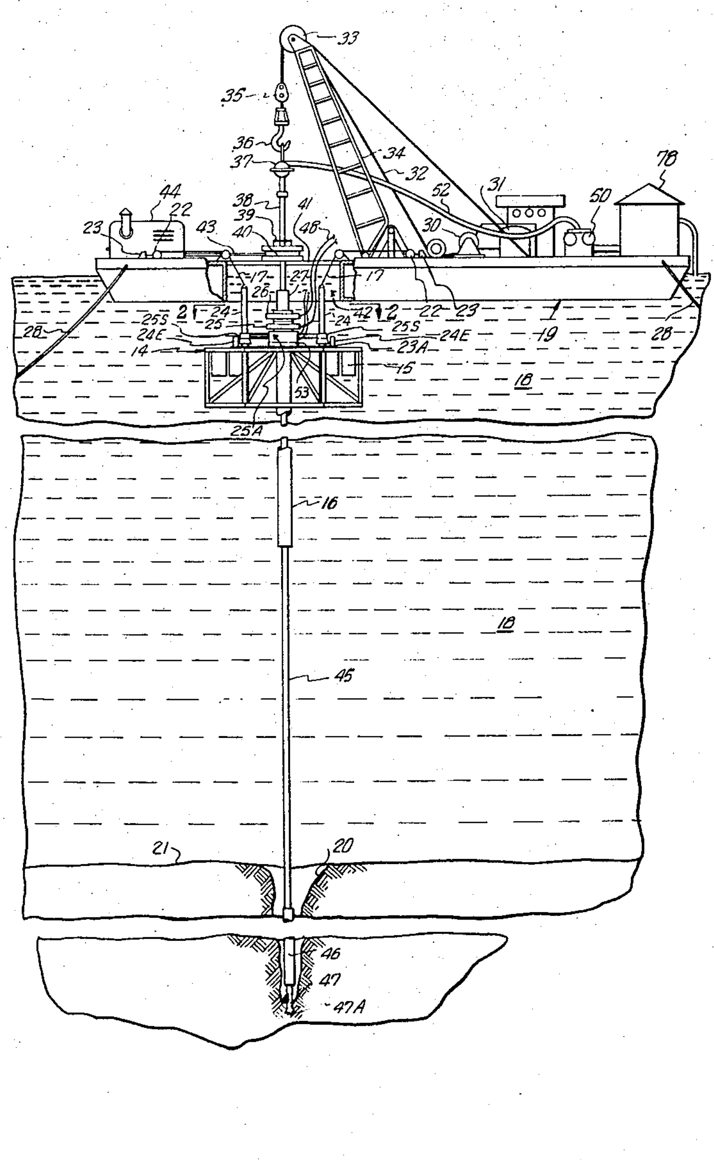
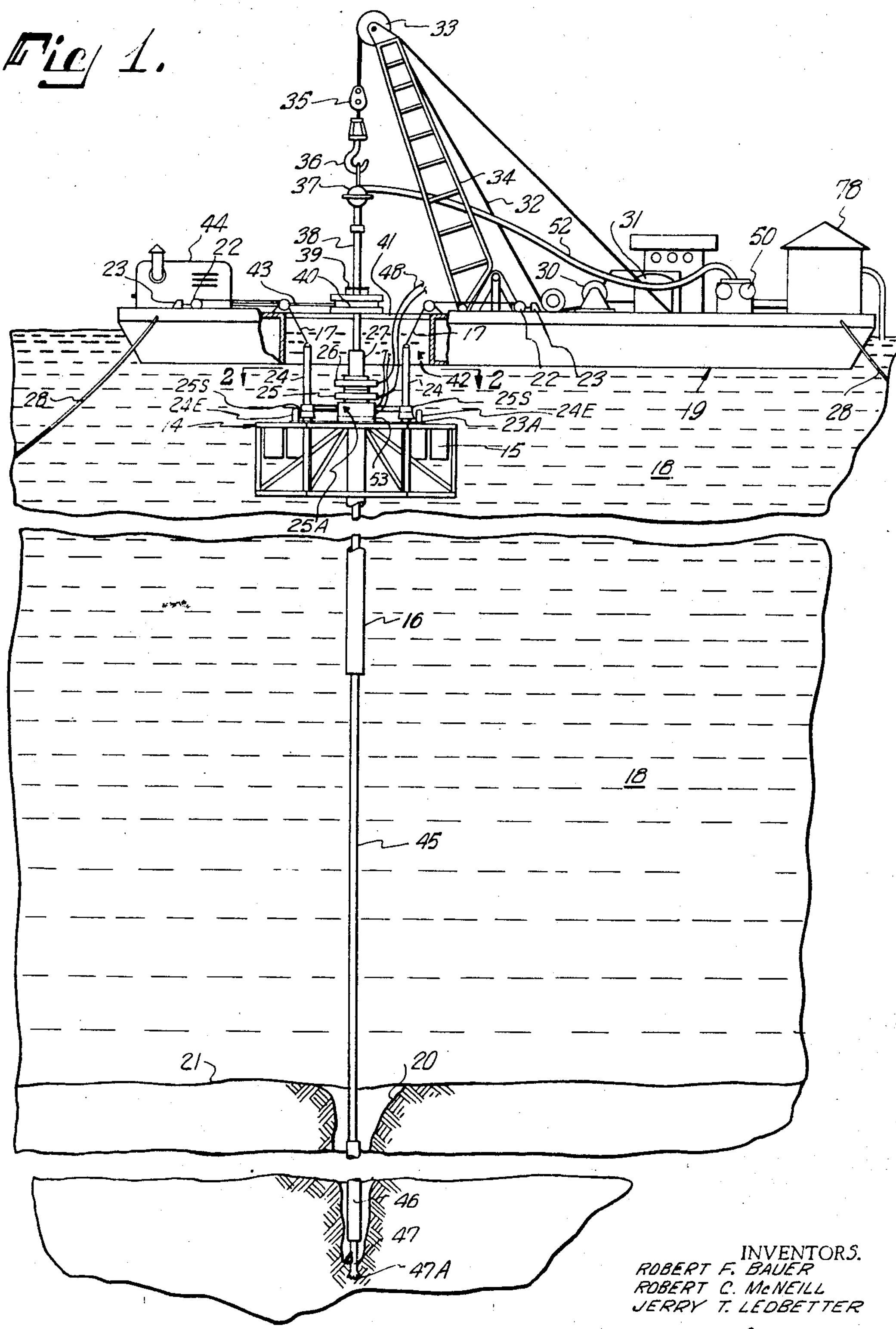


Fig. 1.



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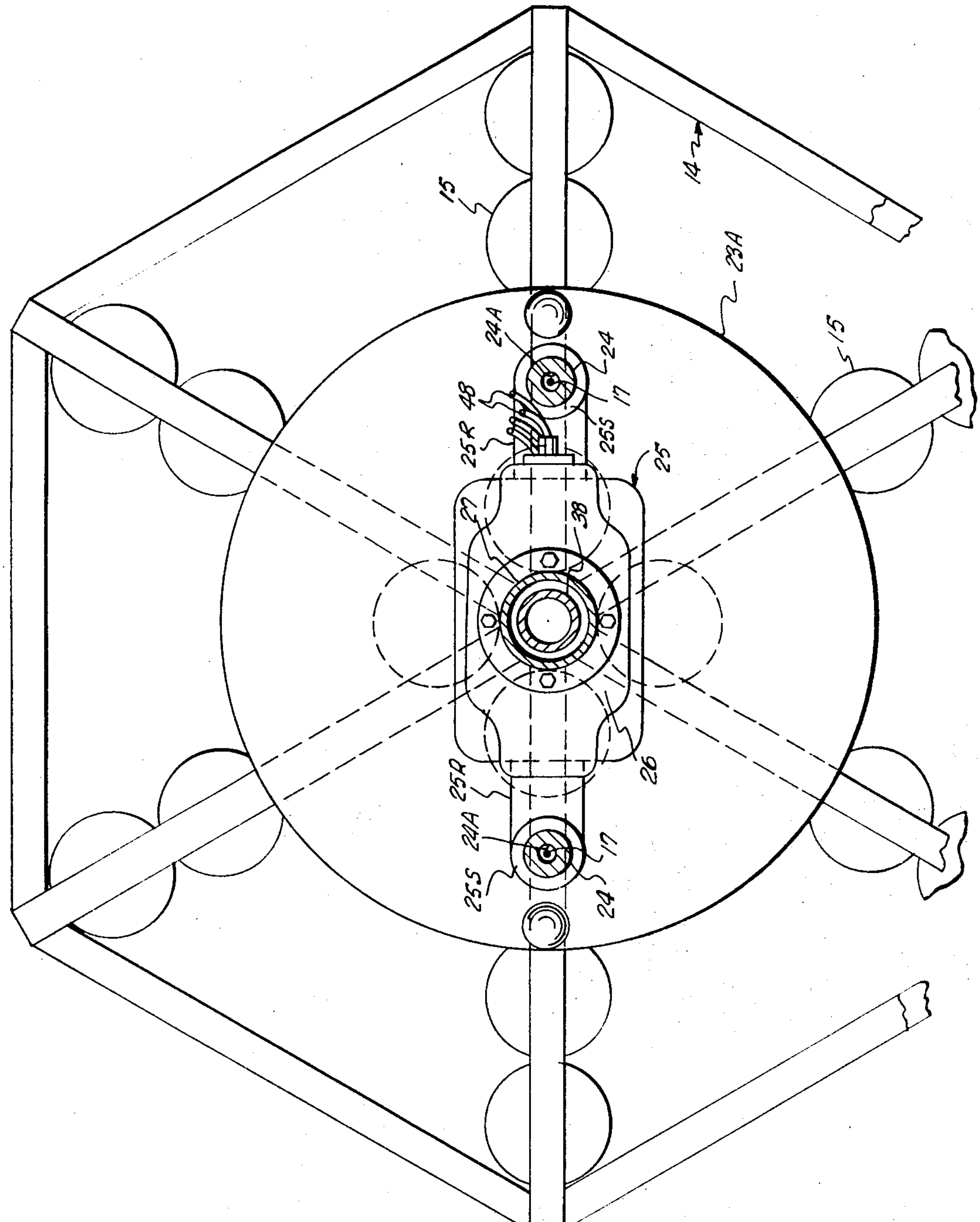

Fig. 2.

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Fig. 3.

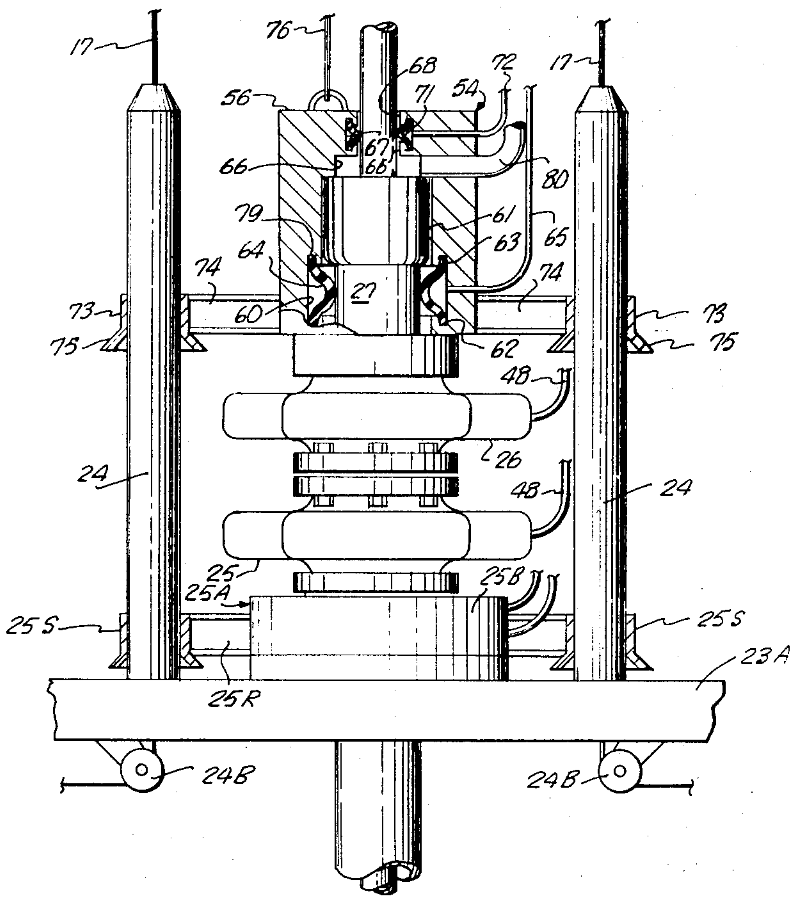

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Fig. 6.

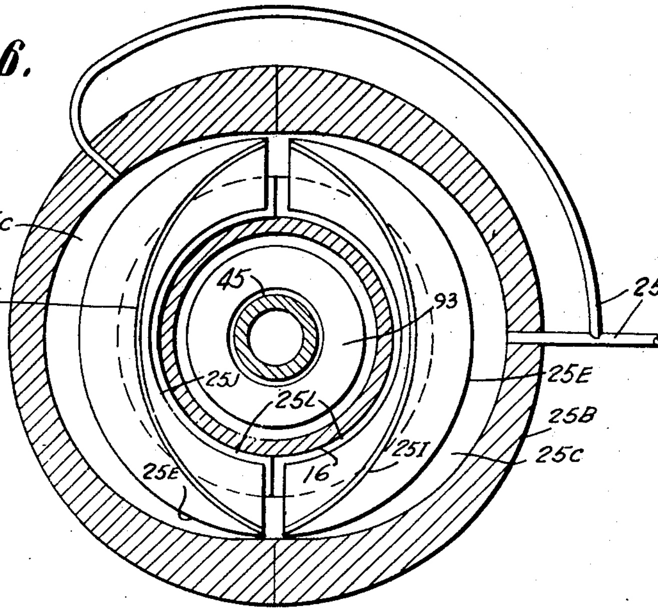

Fig. 4.

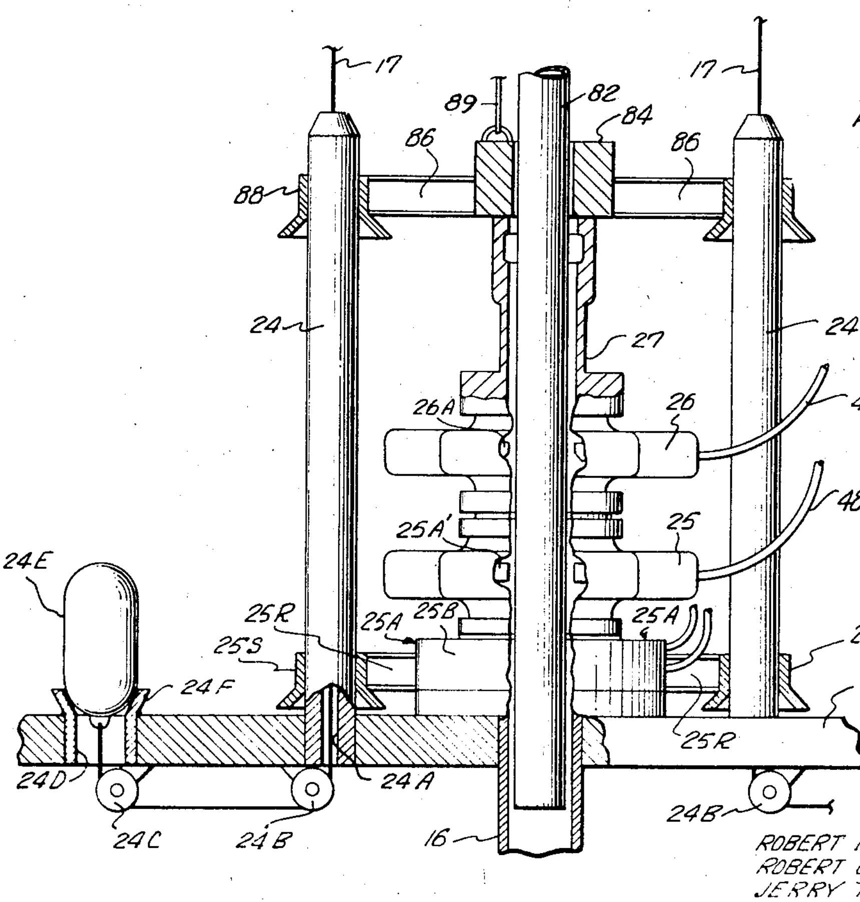

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Fig. 5.

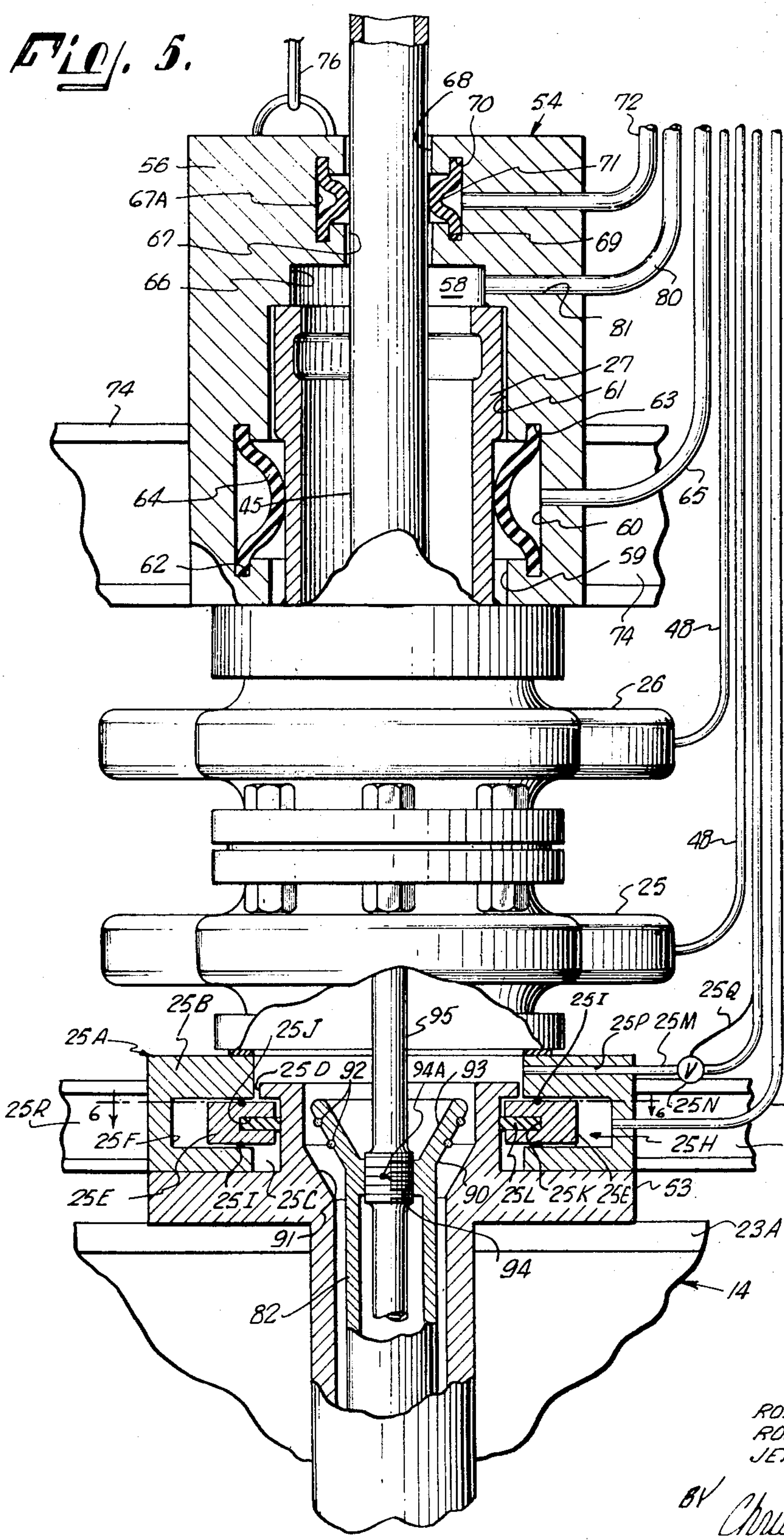

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Fig. 7.

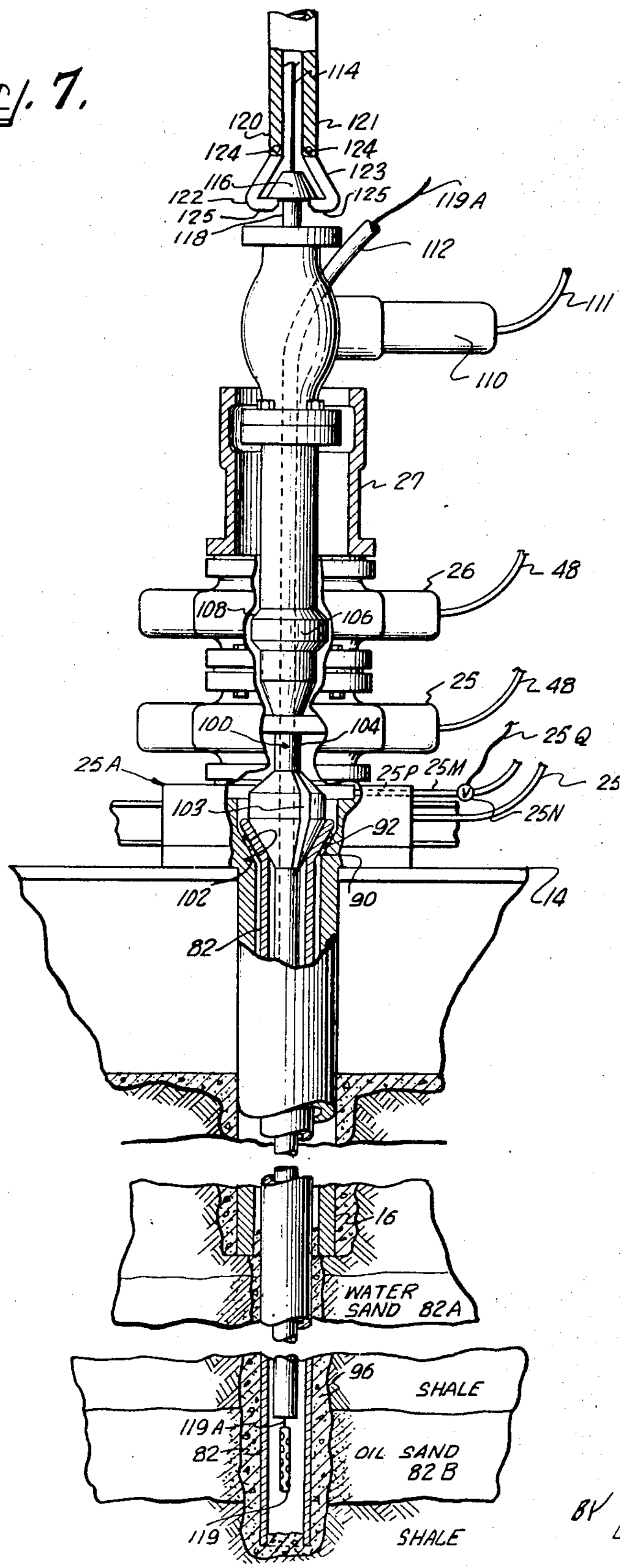

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FIG. 8.

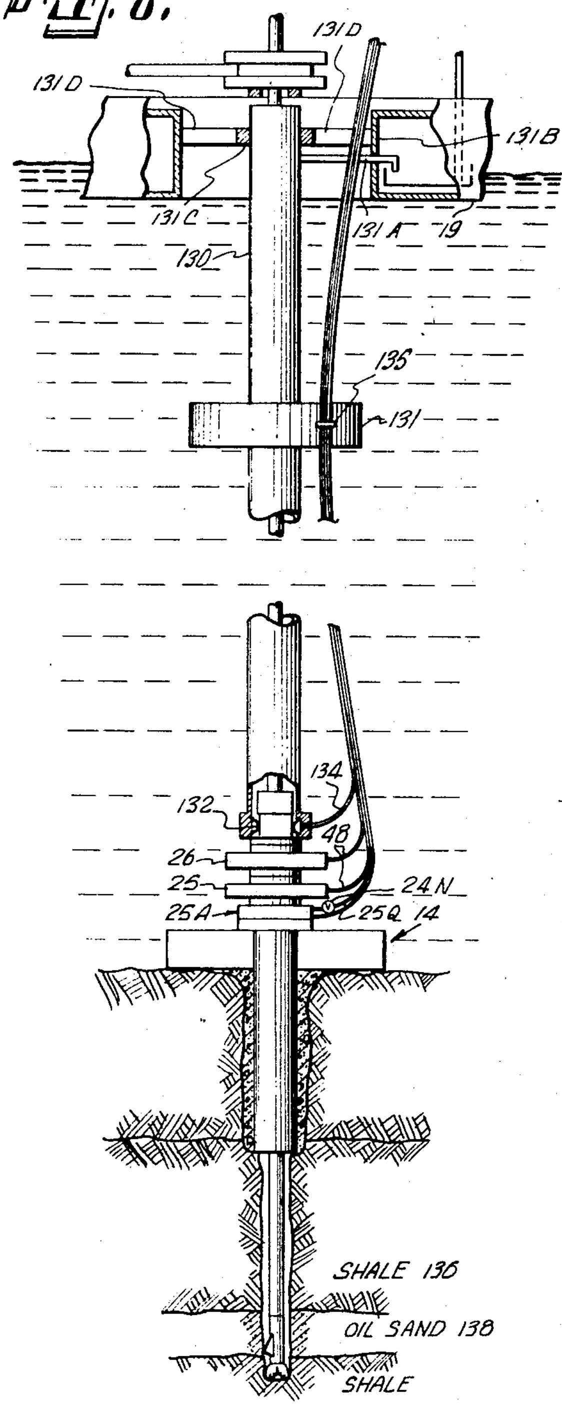

FIG. 9.

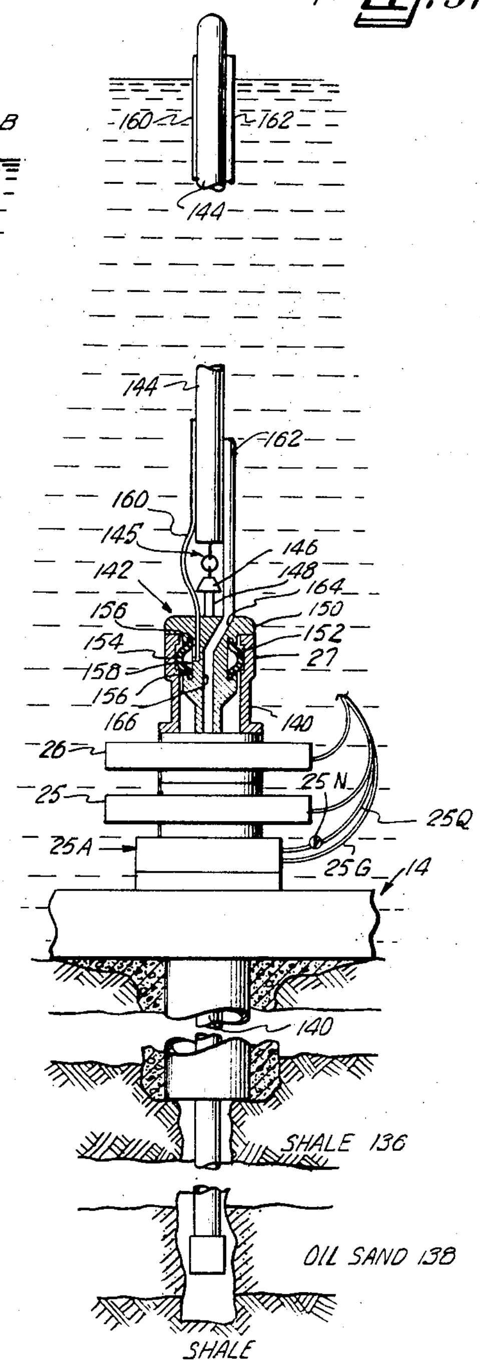

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Fig. 11.

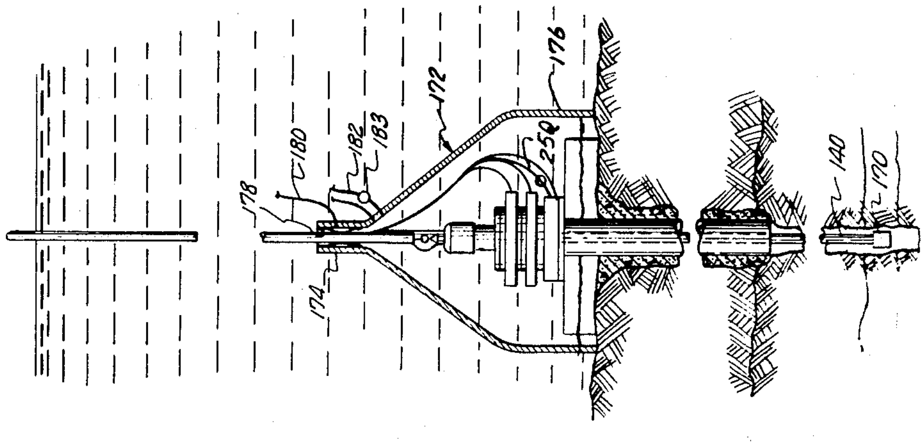

Fig. 10.

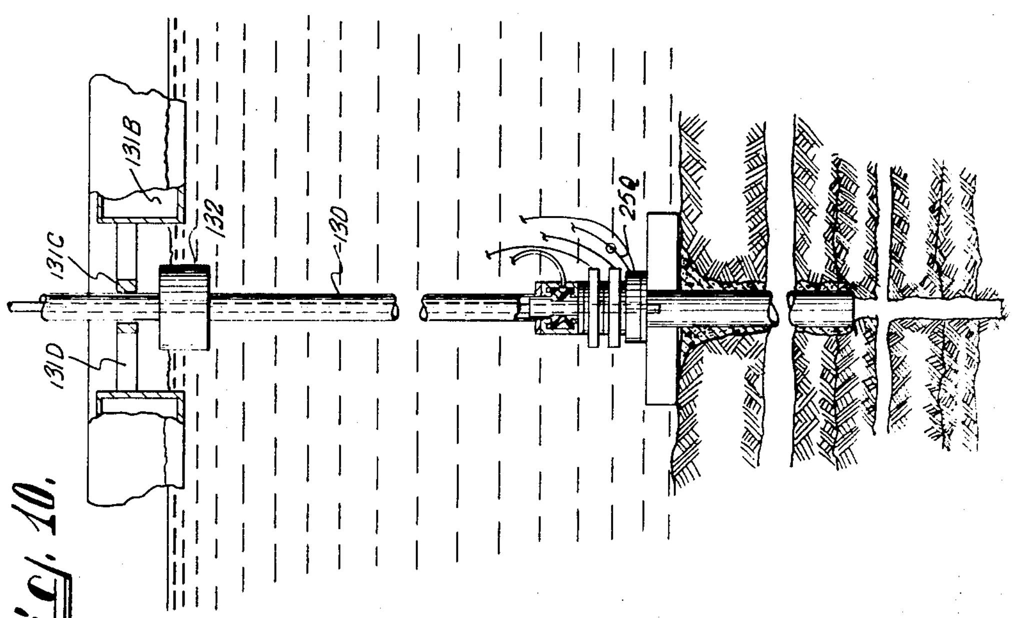

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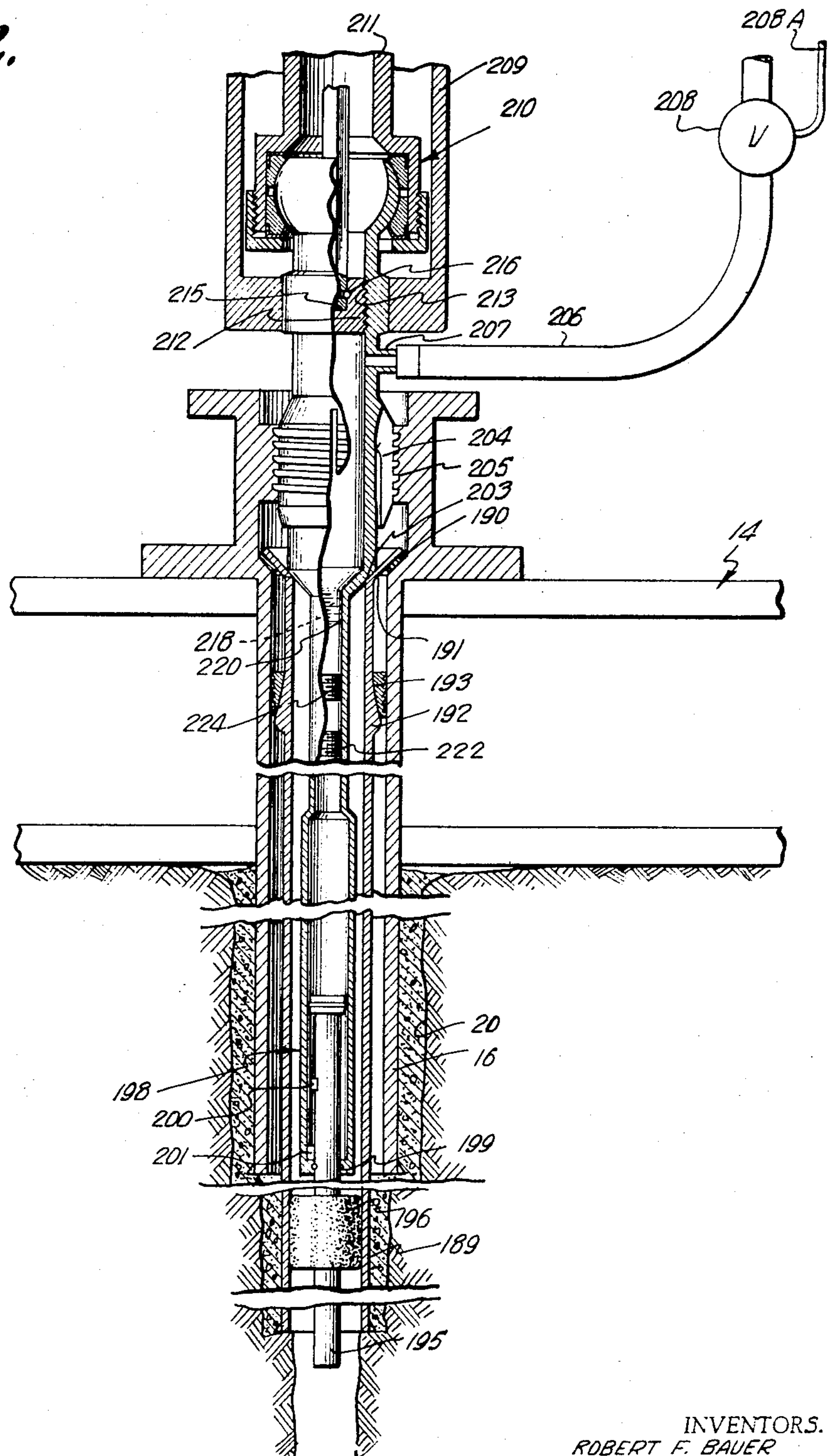
Fig. 12.



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UNDER WATER WELLS

This is a divisional of our copending application Ser. No. 675,714 filed Aug. 1, 1957, which is a continuation-in-part of our application Ser. No. 468,214, filed Nov. 12, 1954, (now U.S. Pat. No. 2,808,229)and relates to underwater wells.

For the purpose of explaining the invention, the following description deals primarily with producing oil and gas wells located under a body of water, although the invention is also applicable to other types of underwater wells, such as water and gas injection wells.

As the search for oil and gas in offshore locations moves to waters of increasing depth, the problem of drilling and completing underwater wells in relatively deep water becomes increasingly complex. At the present time, the underwater producing wells are drilled either from submersible barges in relatively shallow water, or from stationary platforms in the deeper water. In either case, the wells are completed by conventional methods so that the wellhead, christmas tree, and other conventional equipment are located at or near the water surface. Such installations are not only sometimes impractical in relatively deep water, say depths of more than about 50 feet, but also present operational and navigational hazards.

This invention provides apparatus for drilling and completing wells below the water surface so that the wellhead equipment is located at the bottom of the water, or at least well below the water surface so as not to present a navigational hazard.

In terms of apparatus for drilling and completing a well in a formation under a body of water, the invention includes guide means extending between the underwater formation and the water surface for guiding equipment to a well drilled in the formation to a depth sufficient to penetrate a permeable stratum. A casing is sealed in the well. Using the guide means, a fluid conduit is guided to the casing, and means are provided for sealing the casing and the conduit below the water surface in fixed communicating relation.

In one form of the invention, the guide means are a pair of elongated and flexible guide lines anchored at their lower ends adjacent the upper end of the well and supported at their upper ends at the water surface. Preferably, the lower portion of the guide lines are disposed over respective pulleys at the wellhead so that both ends of each guide line extend back toward the surface of the water to permit the ready replacement of the guide lines as required.

In another form, the guide means is an elongated conduit or conductor pipe which opens at its lower end into the well, and which terminates at its upper end at the water surface so equipment can be transferred between the rig and well through the conductor pipe.

In the preferred embodiment, the invention includes a production tubing extending down into the casing, and at least one blow-out preventer attached to the casing and adapted to seal around the tubing and lock it in sealed relationship with the casing.

These and other aspects of the invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic elevation of a floating drilling rig drilling a well in an underwater formation;

FIG. 2 is a view taken on line 2—2;

FIG. 3 is a fragmentary schematic sectional elevation of wellhead circulation equipment used for return circulation of drilling fluid as the well is drilled;

FIG. 4 is a fragmentary schematic sectional elevation of apparatus for guiding a second string of casing into the well;

FIG. 5 is a schematic fragmentary sectional elevation of apparatus for cementing and landing the second string of casing in the well;

FIG. 6 is a view taken on line 6—6 of FIG. 5;

FIG. 7 is a fragmentary schematic sectional elevation of an underwater well completed with the production tubing in place;

FIGS. 8 and 9 are fragmentary schematic sectional elevations of an alternate arrangement for drilling and completing an underwater well without using guide lines;

FIG. 10 is a fragmentary schematic sectional elevation of apparatus used to work over an underwater well;

FIG. 11 is a fragmentary schematic sectional elevation of the well of FIG. 9 after the workover has been completed and a pump installed in the bottom of the well; and

FIG. 12 is a schematic sectional elevation of an alternate embodiment of apparatus for underwater well completion.

Referring to the drawings, FIG. 1 shows a wellhead base or anchor 14, including a plurality of buoyant compartments 15 and a downwardly extending surface casing 16 welded at its upper end to the top of the base, being lowered by a pair of guide lines 17 in a body of water 18 from a floating drilling barge or support 19 toward a well 20 being drilled from the barge in an underwater formation 21.

The upper end of each of the guide lines is wound on a respective winch 22 powered through a torque converter transmission 23 to keep the lines under a constant tension. The lower end of each line passes through a respective vertical guide post 24, welded at its lower end to a circular plate 23A (see FIG. 2) welded to the top of the wellhead base. The two guide posts are located in diametrically opposed positions on each side of the casing of the wellhead base. As shown most clearly in FIG. 4, each guide line extends down into a longitudinal bore 24A in its respective guide post, and passes out the bottom of the post outwardly over a first pulley 24B mounted on the underside of the plate 23A. Each line passes over a respective second pulley 24C and up through a sleeve 24D in the plate where it is connected to a counter buoy 24E held down in an inverted frusto-conical receptacle 24F at the upper end of sleeve 24D.

A first or lower blow-out preventer 25 is connected to the upper end of a locking head or releasable barrel unit 25A, which is secured to the upper end of the wellhead base casing which serves as a safety release joint mandrel. The lower blow-out preventer has rams 25A (see FIG. 4) adapted to close around 4 1/2 inch pipe, such as drill pipe or tubing. A second or upper blow-out preventer 26 is mounted on top of the first and has blind rams 26A (see FIG. 4) so that it can be closed when no pipe is in the casing. A tubular mandrel or receiver 27 is welded to the top of the second blow-out preventer and is collinear with the casing.

The locking head includes an annular body **25B** having a vertical bore **25C** through it, which is of a diameter slightly larger than an outwardly extending lip **25D** on the upper end of the casing. A pair of semi-circular locking plates **25E** are disposed in an internal annular groove **25F** in the locking head body, and are adapted to be moved inwardly and outwardly through fluid pressure, say air, applied through a line **25G** to the annular space **25H** between the plates and the body interior. Arcuate gaskets **25I** in the upper and lower surfaces of the plates make a sliding seal against the top and bottom of groove **25F**, and the outer sides of the plates make a sliding seal against a pair of diametrically opposed straight sections **25F'** in the groove **25F**. The central portion of the inner edge of each plate has a semi-circular cutaway portion **25J** to match the outside diameter of the casing (see FIG. **6**), and also has an internal groove **25K** in which is disposed a semi-circular sealing gasket **25L** that makes a fluid-tight seal around the casing when fluid pressure is applied through line **25G**. The plates make a close sliding fit within the groove in the locking head body and make a similar fit under the casing lip so that the plates form a positive lock for the blow-out preventers to the casing. A "kill" line **25M** is connected through valve **25N** to the interior of the locking head body through a horizontal bore **25P** above the locking plates for a purpose which is explained below. The valve **25N** is actuated through a line **25Q**, which extends to the barge. A pair of brackets **25R** extend outwardly from opposite sides of the locking head body and a separate guide sleeve **25S** on the outer end of each bracket makes a slip fit around the lower portion of a respective guide post. The locking head **25A** and the lower blowout preventor **25** form a housing which can be operated to seal around the casing and around a tubular conduit, such as a drill pipe or tubing.

As shown in FIG. **1**, the barge is anchored over the well by a plurality of suitable anchor lines **28** extending in opposite directions from the barge and connected to anchors (not shown). A draw works **30** and a power unit **31**, which may be of conventional type, are mounted on the barge deck to operate a hoisting cable **32** carried over a crown block **33** on the upper end of a derrick **34** mounted on the barge. The travelling end of the hoisting cable carries a traveling block **35** and a hook **36** which supports a swivel joint **37**. A kelly joint **38** extends downwardly from the swivel through a kelly bushing **39** in the center of a rotary table **40** mounted on gimbals in a manner similar to that described in U.S. Pat. No. Re. 24,083. The rotary table is supported on a platform **41** directly over a cellar **42**, which is located on the centerline of the barge and opens out the bottom of the barge. Power is supplied to the rotary table through a shaft **43** turned by a rotary table power unit **44**.

A string of drill pipe **45** is connected to the lower end of the kelly joint and extends down through the cellar, the receiver, the open blow-out preventers, the locking head, the casing, the water and into the well. Drill collars **46** and a blade-type underreamer **47** with a drill bit **47A** on its lower end are attached to the lower end of the drill pipe for boring the well to a diameter slightly larger than the outside diameter of the wellhead base casing. The blow-out preventers are actuated through control lines **48** which extend from the preventers to the barge.

Drilling as illustraded in FIG. **1** is carried out as follows:

The wellhead base is either towed or carried on the barge to the desired location, and the barge is firmly anchored over the well site. The supporting lines are connected through the guide posts to the counter buoys, and the wellhead base is launched into the water, if carried on the barge.

The upper ends of the guide lines being controlled from the barge, the wellhead base compartments are flooded, say by puncturing the walls of some of the buoyant compartments, until the base has a slight negative buoyancy. The base is then maneuvered into the position shown in FIG. **1**, i.e., directly under the cellar of the barge, where it is held by the lines at a shallow depth. The upper ends of the lines are connected to the winches as shown in FIG. **1**. The drill bit, underreamer, drill collars, and drill pipe are made up on the barge and lowered through the receiver, the blow-out preventers, the locking head, and the casing. Drilling is begun, sea water being circulated by a pump **50** through a mud hose **52** connected to the swivel, and out the drill bit to wash cuttings up out of the hole, no attempt being made to obtain return circulation of drilling fluid at this time. Drilling continues in this fashion until a sufficient depth is reached to permit the casing to be stripped down over the drill pipe into the well and allow the bottom of the wellhead base to rest on the ocean floor.

For operation in areas where the water depth is less than the overall length of the desired amount of casing and the wellhead base, a slightly different procedure is used. The base is maneuvered into the position shown in FIG. **1** without the casing, locking head, blow-out preventers, and receiver. A joint of casing is inserted in the opening of the base and supported by suitable means from the barge so that the lower end of the casing is flush with the bottom of the base. The casing and base are lowered simultaneously, successive joints of casing being added as required, until the base is resting on the bottom, and the upper end of the casing extends up into the barge above the water level. Using salt water without return circulation, sufficient hole is drilled with the bit and underreamer to receive the desired amount of casing. Salt water is then displaced with drilling mud to keep the hole open, and the bottom of the casing is lowered a few feet into the upper end of the hole. The drill pipe is withdrawn from the hole and casing, and the remainder of the casing is then run down into the hole, additional joints of casing being added as required. The locking head, blow-out preventers and receiver are secured to the upper end of the casing, and the lower end of the drill pipe is disposed within the upper end of the casing so that it extends down below the blow-out preventers. The blow-out preventers are then closed around the drill pipe, and the upper end of the casing is lowered by means of the drill pipe so that the locking head guide sleeves slide down the guide lines onto the posts until an outwardly extending flange **53** formed integrally near the upper end of the casing rests on the plate **23A** on top of the wellhead base.

The casing is cemented in place by pumping cement down through the drill pipe and forcing the cement into the annular space between the casing and the hole. The cement is followed by drilling mud which displaces the cement from the upper portion of the casing to a point below the drill bit. The cement is then allowed to set. The drill bit may either be removed immediately or drilling may proceed to such a depth that it is necessary to replace the bit or provide for return circulation of drilling mud to support the walls of the well bore. At this point is is necessary to have apparatus which permits equipment to be guided accurately to and from the well bore. Such apparatus is shown in FIG. 3.

Referring to FIGS. 3 and 5, a circulating head **54** includes a cylindrical body **56** having a central vertical opening **58** extending through it. Beginning at the bottom of the circulating head, the lower portion of the central opening includes a first relatively short bore **59**, followed by a second bore **60** of increased diameter, which is in turn followed by a third bore **61** of the same diameter as the first bore. An upwardly opening annular groove **62** is formed in the shoulder between bores **59** and **60**, and a downwardly opening groove **63** is formed in the shoulder between bores **60** and **61**. A flexible receiver sealing sleeve **64** is molded at opposite ends into grooves **62** and **63**. The sleeve is adapted to be expanded into sealing contact against the receiver when the circulating head is in the position shown in FIG. 3 by fluid pressure applied through a line **65** connected to the annular space between sleeve and bore **60** and to a source of fluid pressure (not shown) on the barge.

Third bore **61** is followed by a fourth bore **66** of smaller diameter, which in turn is followed by a fifth bore **67** of yet smaller diameter, a sixth bore **67A** of increased diameter, and then by a final bore **68** of a diameter equal to that of the fifth bore. An upwardly opening annular groove **69** is formed in the shoulder between bores **67** and **68**, and a downwardly opening annular groove **70** is formed in the annular shoulder between bores **67A** and **68**. A flexible drill pipe seal sleeve **71** has its ends molded in grooves **69** and **70**. The drill pipe sealing sleeve is forced against the drill pipe to make a seal against the pipe by means of fluid pressure applied through a line **72** connected to the annular space between the sleeve and bore **67A** and to a source of fluid pressure (not shown) on the barge.

The circulating head is adapted to be guided up and down the guide lines by a pair of guide sleeves **73** attached by I-beam brackets **74** on opposite sides of the circulating head. As can be seen most clearly in FIG. 3, the guide sleeves are adapted to make a sliding fit over the guide posts and have frusto-conical skirts **75** on their lower ends to facilitate mating with the upper ends of the guide posts, which are chamfered. The guide posts each extend a substantial distance above the upper end of the receiver so that, as the circulating head is lowered, the guide sleeves slip on the posts and align the opening of the circulating head with the receiver before the bottom of the circulating head reaches the upper end of the receiver.

To obtain return circulation with the circulating head of FIG. 3, it is lowered by a line **76** down the drill pipe toward the position shown in FIG. 3, the guide sleeves first being slipped over the guide lines on the barge. When the bottom of the circulating head rests on the top of the upper blow-out preventer, pressure is then applied through line **65** to seal the circulating head to the receiver. Pressure is also applied to the drill pipe seal through line **72** sufficient to prevent leakage of drilling fluid and yet permit rotational and longitudinal movement of the drill pipe in the seal. Drilling mud is circulated from a mud tank **78** (see FIG. 1) on the barge through the mud hose, kelly joint, drill pipe, out the lower end of the drill bit, up the annular space between the drill pipe and the well, back to the circulating head, out a lateral mud return conduit **79** in the circulating head, and back to the mud pit through a mud return line **80** connected at its lower end to a horizontal bore **81** which opens into the circulating head above the receiver seal.

Drilling is continued until such time that a string of protective or secondary casing **82** must be set, say to shut off a water sand **82A** from an oil sand **82B** penetrated by the well.

The apparatus of FIG. **4** shows how a string of secondary casing **82** is started into the well. The circulating head is released from the well by removing the fluid pressure from lines **65** and **72**, and is raised to the surface by line **76**, or else is raised to the surface by lifting the drill pipe so that the drill bit moves up into the circulating head and engages the shoulder between bores **66** and **67** to lift the circulating head to the surface.

With the drill pipe out of the well, and drilling mud still in it, the lower end of the secondary casing **82** is disposed in a tubular casing guide **84** which has a pair of outwardly extending bracket arms **86**, each of which has a respective guide sleeve **88** on its outer end adapted to slide down the guide lines and on to the guide posts as shown in FIG. **4**. Thus, the casing and casing guide are lowered together so that the lower end of the casing is within the guide and brought into collinear alignment with the receiver as the guide seats on the receiver. The casing is then slipped down through the casing guide and receiver into the well, the upper end of the casing being supported from the barge. Once the casing is started into the well, the casing guide is raised by a line **89** attached to it. Lowering of the casing into the well is continued, additional sections of casing being added as required.

As shown in FIG. **5**, the uppermost section of the protective casing string includes an outwardly and upwardly extending external landing seat **90** on its upper end, which is adapted to rest on a matching landing seat **91** in the conductor pipe just below the first blow-out preventer. The external seat of the secondary casing includes a series of O-rings **92** to effect a fluid-tight seal against the first casing. The upper end of the secondary casing string includes an outwardly and upwardly extending internal seat **93** to support a string of tubing as described in detail below. The upper end of the protective casing string also includes an internally threaded section **94** of left-hand threads, which receive matching external threads **94A** of an adapter **95** made up in the string of drill pipe. Thus, when the uppermost section of casing is added to the protective casing string at the barge, a short section of drill pipe is lowered into the upper end of the casing, hollow adapter **95** is connected in the drill string, and additional sections of drill pipe are coupled above the adapter. The adapter is screwed into the casing, and the casing is lowered to the position shown in FIG. **5** by adding on additional sections of drill pipe and lowering the entire assembly on the drill pipe. The circulating head is then made up over the drill pipe and lowered to the position shown in FIG. **5** and sealed to the mandrel and around the drill pipe. If necessary, mud is circulated through the well to clean out the well and place the mud in proper condition for cementing the secondary casing in place. Cement is then pumped down the drill pipe to force drilling fluid out of the annular space between the second string of casing and the well bore. Preferably, the casing is moved up and down with the drill pipe to insure uniform distribution of the cement. After the required amount of cement is pumped into the well and properly placed by displacement with mud, the casing is lowered to the position shown in FIG. 7 so that its external seat rests on the internal seat of the conductor. The drill pipe is then rotated to unscrew the adapter from the casing, and the drill pipe is withdrawn. Although only one protective string has been shown as necessary to reach the oil producing sand to simplify the explanation of the invention, as many protective strings as required may be set by following the foregoing procedure.

After the cement has set in the position shown in FIG. **7**, the lower end of a tubing **100** is lowered into the upper end of the casing **82** in the well **20** by using a guide device similar to that shown for the casing in FIG. **4**. The upper end of the tubing has an external seat **102** adapted to rest on the internal seat of the protective secondary string of casing. A vertical groove **103** in the tubing seat provides communication between the locking head interior above the tubing seat and the annular space between the tubing and casing. The tubing includes a short section of pipe **104** just above its seat around which the rams of the lower blow-out preventer are adapted to close and seat. Just above the section **104**, the tubing includes a section **106** of enlarged diameter having upwardly and inwardly sloping shoulders **108** against which the blind rams of the upper blow-out preventer bear when the upper preventer is closed. The under surface of the inside edges of the blind rams are tapered to match the slope of tubing shoulder **108**.

A control valve **110** actuated by a control line **111** extending to the barge is on the upper end of the tubing, and a flow line **112** extends from the valve to the water surface, either to the shore line or to a floating island (not shown) on which the oil produced from the well is collected, separated, and then pumped to bulk storage.

The tubing is lowered to the position shown in FIG. **7** by a line **114** connected to the upper end of a frustoconical boss **116** mounted on a lifting post **118** welded to the top of the tubing valve **110**. Once the drilling barge leaves the well site, line **114** is buoyed at its upper end so that the well may be easily reloacted for further service as required. The blow-out preventer rams are closed by their respective control lines, which are also buoyed along with the valve control line at the water surface after the barge leaves the well site. Preferably, the guide lines are carried away from the well a suitable distance and held there by anchors (not shown) to prevent fouling with the other lines.

After the tubing is placed as shown in FIG. **7**, the drilling mud is displaced from the well by pumping a lighter fluid such as oil or gas down line **25M** and into the annular space between the tubing and secondary casing. A gun perforator **119** suspended from the tubing by a line **119A** is used to perforate the casing and cement to the producing formation. After the perforating operation, the gun is withdrawn to the barge by line **119A**. Line **25M** is closed by valve **25N** and oil flows from the sand up the tubing and line **112**. Thus, the tubing **100**, valve **110**, and flow line **112** form well completion equipment releasably engaged with the casing **82** in the well **20**.

Any time the tubing needs to be removed, for example to permit working over the well, the barge is anchored over the well site again, and the various buoys and lines are picked up and mounted on the barge as described previously. If necessary, the well is killed by pumping a heavy fluid into it. The blow-out preventers are opened, and a tubing pulling tool **120** comprising an elongated tubular body **121** and a latch **122** on the lower end of the body is lowered down over tubing line **114** so that the latch engages the projection on boss **116** as shown in FIG. **7**. The latch includes a pair of diametrically opposed and downwardly extending fingers **123** secured by separate respective horizontal pivot pins **124** at their upper ends to the lower end of body **121** to pivot about pins **124**. The lower end of each finger includes an inwardly extending catch **125** which is forced outwardly as the latch slides down over the boss **116** until the catches are below the bottom of the boss and drop to the position shown in FIG. **7**. The tubing is then lifted out of the well by raising the tubing puller. After the necessary remedial work is completed, the well is recompleted as described above.

In some cases, it is preferable to drill and complete an underwater well without using guide lines as described above, and FIGS. **8** through **11** show method and apparatus for such an operation. In this case, the wellhead base, casing, blow-out preventers and locking head are landed and cemented in place as previously described. However, instead of using a circulating head, a conduit **130** is located on the mandrel by stripping the conduit down over the drill pipe, which extends from the drilling barge into the mandrel. A buoyant chamber **131** is attached to the upper portion of the conduit below the water surface and provides support for the conduit. A lateral mud conduit **131A** carries mud to a mud pit **131B**. The upper end of the conduit is centered in the cellar of the barge by a stabilizing ring **131C** supported by a spider **131D** secured to the sides of the cellar in the barge. The lower end of the conduit includes an internal seal **132** (FIG. **8**) similar to the locking head seal, and it is adapted to be actuated by fluid pressure through line **134** so that the lower end of the conduit can be locked and sealed to the mandrel as shown in FIG. **8**. The various control lines coming from the wellhead are secured by a clamp **135** to the buoyant chamber. To simplify the explanation of the invention, it is assumed that the wellhead base casing is of sufficient length to give the desired support to the well, and that the formation below the wellhead conductor is competent to permit an open hole completion. Of course, additional string of casing can be set through the conductor, if required.

The well is drilled through a layer of shale **136** into an oil sand **138**. With drilling mud in the well to prevent oil flow, the drill pipe is removed from the well, and a tubing **140** (see FIG. **9**) is started down into the well through the surface conduit and supported from the drilling barge. Additional lengths of tubing are made up and lowered in the well until the upper end of the tubing is reached. A tubing head **142** is secured to the upper end of the tubing and lowered onto the position shown in FIG. **9** by a buoyant tubing post **144** connected at its lower end through a swivel joint **145** to a frusto-conical projection **146** mounted on the upper end of a post **148** welded to the top of the tubing head.

An outwardly extending flange **150** on the upper end of the tubing head is adapted to rest on the upper end of the receiver which has an internal annular groove **152** to receive a sealing sleeve **154** molded at each end into downwardly and upwardly opening respective annular grooves **156** at each end of an annular groove **158** around the tubing head. Fluid pressure is applied to the interior of the tubing seal through a line **160** which opens into the annular space between the tubing seal and the tubing head. A flow line **162** is connected to a diagonal bore **164** in the top of the tubing head which opens at its lower end into a vertical bore **166** which in turn opens its lower end into the tubing. The maximum outside diameter of the tubing head is the same as the maximum outside diameter of the receiver so that the tubing and its head can be lowered inside the conduit **130**.

With the tubing in the position shown in FIG. **9**, the tubing seal is actuated through line **160** to seal the tubing head to the interior of the receiver. Preferably, the tubing has an enlarged projection (not shown) similar to that of the tubing shown in FIG. **7** so that the blind reams of the upper blow-out preventer can be closed against it to serve as a positive hold down, and the portion of the tubing adjacent the rams of the lower blow-out preventer is of such a diameter that the rams of the lower blow-out preventer make a fluid-tight seal against it when closed. Mud is displaced from the well through flow line **162** by pumping a light fluid such as oil and gas down line **25M**, through valve **25N**, and into the locking head. When the hydrostatic head of the fluid in the well is sufficiently reduced, the pressure of the oil in the oil sand causes oil to flow up the tubing and out flow line **162**, where the oil is collected and stored by any suitable means (not shown). Valve **25N** is then closed to shut in line **25M**.

Once the well is completed as shown in FIG. **9**, conduit **130** is removed, and the control lines are disconnected from the barge and buoyant chamber, sealed, buoyed and cast off with the exception of the control line **134** for the conduit seal, which is removed with the conduit from the well. Thus, the location of the underwater well is marked by the buoyant tubing post which has a smooth exterior surface that is not readily fouled by fishing nets, flotsam, jetsam, kelp, etc.

If it should be necessary to work over the well, say to install a pump, the barge is returned to the position shown in FIG. **10**, and the tubing is raised either by the tubing post or else by a tubing puller as previously described with respect to FIG. **7**. If necessary, the well is killed by the injection of a heavy "kill" fluid. The conduit **130** is either stripped down over the tubing post, before the tubing is lifted from the well, or else is stripped down over the tubing after the tubing has been partially removed from the well. Once the conduit seal is around the receiver, it is sealed in the position shown in FIG. **10**. All of the tubing is then withdrawn to the surface, and a pump **170** (see FIG. **11**) which may be of conventional type, is assembled on the lower end of the tubing, which is then lowered back into the well through the conduit. Additional sections of tubing are added at the barge and the tubing is again seated as shown in FIG. **9**. Once the tubing is sealed in the well, the surface conduit is removed and the pump is placed in operation so that the well is now a pumping well instead of a flowing well. If the well was killed by heavy fluid prior to the setting of the pump, the "kill" fluid is removed by the application of a lighter fluid through line **25Q** as previously described.

FIG. **11** also shows apparatus for protecting the wellhead equipment from deterioration such as rust and barnacle attachment while under water. A frusto-conical envelope **172** having a neck **174** opening out of its upper end and a cylindrical skirt **176** projecting down from its lower end is slipped down over the buoyant tubing post and various control lines which extend up through the neck of the envelope. The skirt of the envelope rests on the ocean bottom around the wellhead base. An elastic sleeve **178** is secured at each end to the interior of the envelope neck and a line **180** supplies fluid pressure to the annular space between the neck and sleeve **178**. Thus, the sleeve **178** can be forced to effect a fluid-tight seal around the buoyant posts and control lines. A suitable protective fluid such as gas, oil, or even water with a suitable inhibitor dissolved in it, is pumped down through the envelope through a line **182** and check valve **183** to displace the sea water at least down to a level below the top of the wellhead base. Thus, the wellhead equipment is protected from barnacles, corrosion, and other adverse effects of the underwater environment.

If one of the wells shown in the drawings is to be permanently abandoned, the well is filled with cement (not shown) or otherwise suitably shut in, and the drill pipe withdrawn. Pressure is released from the blow-out preventer locking head through line **25G** so that the conductor, blow-out preventers, and locking head can be lifted from the casing. As shown most clearly in FIG. **5**, when the pressure in line **25G** is reduced, the hydrostatic head of water pressure forces the locking plates outwardly so that the locking head can be lifted from the casing. If the hydrostatic head is not sufficient to retract the locking plates, additional pressure may be applied through the kill line **25M** and valve **25N** to the interior of the locking plates, the blow-out preventers being set to shut off communication with the circulating head, or conduit **130**. The kill line has the additional function of permitting a heavy fluid to be pumped down into the well in the event of a threatened blow-out and when the well is shut in by the blow-out preventers.

If the well is not to be permanently abandoned, but the blow-out preventers require replacement or repair, a drill pipe or other suitable guide is left in the well, and the locking head is released from the casing so that the circulating head or conduit **130**, blow-out preventers, and locking head can be lifted, say, with the draw works, to the barge over the drill pipe. After the necessary repairs or replacements have been made, the locking head, blow-out preventers, and circulating head or conduit **130** are stripped back down guide means such as the drill pipe, or guide lines, if used and into the sealing position shown in FIGS. **5** or **11**.

An alternate embodiment of apparatus for underwater well completion is shown in FIG. **12** in which the well base and surface casing are landed in the well by any suitable technique, say as shown in FIG. **8**. An oil string casing **189** is landed on a heavy elastic gasket **190** on an internal seat **191** in the receiver as described previously with respect to FIGS. **4** and **5**. The oil string casing of FIG. **12** includes an outwardly and downwardly extending external protuberance **192** a short distance below its upper end. A set of slips **193** are disposed on the protuberance and adapted to engage the interior of the surface casing and prevent upward displacement of the oil string. As the oil string of FIG. **12** is seated in a manner similar to that described with respect to FIG. **5**, the upper end of the oil string is subjected to a reciprocating motion to drive and pound the slips as far down inside the surface casing as possible. The gasket **190** absorbs some of the shock and effects a tight seal between the internal landing seat and the receiver.

After the casing is cemented in place, as previously described, a production tubing **195** is lowered into the well through the conduit (not shown in FIG. **12**) sealed to the receiver (not shown in FIG. **12**) and extends to the drilling barge (not shown in FIG. **12**). The lower end of the tubing includes a production packer **196** which may be of the conventional type and which is adapted to be set by rotation of the tubing and the application of tubing weight. The tubing includes a slip joint **198** above the packer, and the lower portion of the tubing is adapted to rotate and slide longitudinally through a seal **199** in the lower end of the slip joint. An external dog **100** on the portion of the tubing in the slip joint is adapted to engage an internal dog **201** at the lower end of the slip joint. Thus, as the tubing is lowered into the well, the external dog rests on the bottom of the slip joint so the two dogs are engaged. The packer makes a loose sliding friction fit against the casing, and when lowered to the desired location, is set by rotation of the tubing. The packer is then set hard by lowering the upper end to the tubing to place the weight of the lower portion of the tubing on the packer. This also disengages the dogs.

The upper portion of the tubing includes an external landing seat **203** adapted to land on the upper end of the oil string casing. A plurality of outwardly and downwardly extending fingers **204** with left-hand threads are attached to the tubing exterior above its landing seat and engage an internally threaded sleeve **205** in the receiver interior. Thus, as the upper end of the tubing is lowered after the packer is set, the fingers are deflected inwardly and slip down through the internally left-hand threaded sleeve until the tubing lands on its seat. The fingers then spring outwardly to engage the threaded sleeve and hold the tubing down in the well. Preferably, the tubing is landed with the well full of a heavy drilling fluid so the annular space between the tubing and oil string above the packer is filled with the fluid, thereby adding to the force tending to hold the tubing and oil string down in the well against formation pressure.

When desired, the tubing then is released by rotating it in a right-hand direction to disengage the left-handed thread, thereby avoiding having to turn the tubing in a left-hand direction, which might accidentally uncouple the tubing. The packer is unseated as the upper end of the tubing is raised to cause the slip joint to take the weight of the lower portion of the tubing off the packer.

A production flow line **206** is connected at its lower end to a lateral conduit **207** in the tubing just above the locking fingers. The flow line extends to the water surface and includes a valve **208** actuated through a fluid line **208A** to permit the flow line to be closed when desired. A secondary receiver **209** is welded at its lower end to the tubing exterior just above the lateral conduit for a purpose described in detail below.

A sealed socket joint **210** connects the lower end of a buoyant guide tubing guide post **211**, such as shown in FIG. **9**, to the upper end of the tubing inside the secondary receiver. The socket joint permits the buoyant post to be deflected laterally in all directions.

A first or upper externally threaded tubing plug **212** is threaded into an internally threaded section **213** in the tubing between the socket joint and the lateral conduit outlet **207**. The threads of the tubing plug are left-handed, and it is inserted or removed by an elongated plug rod of square cross-section at its lower end, which is adapted to fit into a matching opening **215** in the upper end of the plug. A detent **216** holds the plug on the lower end of the rod while the plug is being raised and lowered. Once the plug is installed as shown in FIG. **12**, the rod may be removed, if desired, by overcoming the holding force of the detent. To shut the well in, say for repair to the wellhead equipment, a second or lower tubing plug **218** (shown only in phantom line) may be installed in a second threaded portion **220** in the tubing below the tubing landing seat.

The tubing also includes the usual safety devices such as a storm choke **222**, which is adapted to close when fluid flow through the tubing exceeds a predetermined value. The tubing also includes a choke or bean **224**, such as an Otis choke or other suitable subsurface flow control equipment.

Any time it is desired to work over the well shown in FIG. **12**, a conduit of the type shown in FIG. **8** is stripped down over the buoyant guide post and sealed at its lower end to the secondary mandrel. If desired, the conduit includes conventional lubricating means for sealing the upper end of the conduit at the barge so that the conduit interior can be pressurized and tools or equipment moved to and from the well through the conduit at well pressure.

It will be noted that the apparatus of FIG. **12** accomplishes hold-down of the tubing and casing without blow-out preventers by using the casing slips **193** and the tubing fingers **204**.

It will be obvious to those skilled in the art that additional equipment such as storm chokes, adjustable flow beans, etc., can be installed for any degree of safety and control required by various situations without departing from the scope of this invention.

We claim:

1. In combination with a well drilling string, apparatus for drilling a well in a formation under water, comprising: a support; a casing positioned in said formation and having its upper end substantially at the

surface thereof, said casing being fixed to said formation; a safety release joint mandrel secured to the upper end of said casing; a guide extending between points in fixed relation to said upper end of said casing and said support; a vertical assembly of series connected devices terminating at their lower end in a safety release joint barrel unit, said unit being matable with said mandrel; and means on said assembly for slidable engagement with said guide.

2. In combination with a well drilling string, apparatus for drilling a well in a formation under water, comprising: a support; a casing positioned in said formation and having its upper end substantially at the surface thereof, said casing being sealingly cemented in said formation; a safety release joint mandrel secured to the upper end of said casing; an anchor device secured to said casing; guide means extending between said anchor and said support; a vertical assembly of submerged devices including a safety release joint barrel unit, said unit being matable with said mandrel; means on said assembly for slidable engagement with said guide means; and means including connections and apparatus extending from said support for operating said submerged devices of said apparatus.

3. Apparatus for drilling and working in a well submerged under a body of water comprising a platform at the surface of a body of water above a submerged well site, wellhead equipment submerged in said water at said well site, a conduit extending downwardly from said platform through said water to said wellhead equipment, means on said platform for raising and lowering said conduit through said water, a remotely controllable connector for connecting and disconnecting said conduit and said wellhead equipment, said connector comprising a housing secured to the said conduit and having an opening therethrough in axial alignment with said conduit, securing means mounted in said housing and movable transversely with relation to the axis of said opening to project inwardly into said opening and to retract outwardly from said opening, operating means to move said securing means into the opening through the housing, a remote control means on said platform for said operating means, an exterior portion of said submerged wellhead equipment constructed to be received within said opening in said housing in axial alignment therewith, a circumferential recess in said exterior portion, and complementary engaging means on said wellhead equipment and on said connector housing disposed to engage each other in concentric relationship as said conduit is lowered from said platform and to position said connector on said wellhead equipment with said securing means in transverse alignment with said circumferential recess to be disposed in said circumferential recess when said securing means is moved into the opening through the housing.

4. Apparatus for drilling and working in a well submerged under a body of water comprising a platform at the surface of a body of water above a submerged well site, wellhead equipment submerged in said water at said well site, a conduit extending downwardly from said platform through said water to said wellhead equipment, means on said platform for raising and lowering said conduit through said water, a remotely controllable connector for connecting and disconnecting said conduit and said wellhead equipment, said connector comprising a housing secured to by the said conduit and having an opening therethrough in axial alignment with said conduit, securing means mounted in said housing and movable transversely with relation to the axis of said opening to project inwardly into said opening and to retract outwardly from said opening, operating means to move said securing means into the opening through the housing, a remote control means on said platform for said operating means, an exterior portion of said submerged wellhead equipment constructed to be received within said opening in said housing in axial alignment therewith, and complementary engaging means on said wellhead equipment and on said connector housing disposed to engage each other in concentric relationship as said conduit is lowered from said platform and to position said connector on said wellhead equipment with said securing means in transverse alignment with said exterior portion to be disposed against said exterior portion when said securing means is moved into the opening through the housing.

5. Apparatus for drilling and working in a well submerged under a body of water comprising a platform at the surface of a body of water above a submerged well sit, a wellhead equipment pipe submerged in said water at said well site and opening toward the water surface, a conduit pipe extending downwardly from said platform through said water to said wellhead equipment pipe, means on said platform for raising and lowering said conduit pipe through the water, a remotely controllable connector secured to one of the said pipes for connecting and disconnecting said conduit pipe and said wellhead equipment pipe, said connector comprising a housing portion secured to one of the pipes and having an opening therethrough in axial alignment with said conduit, securing means mounted in said housing portion and movable transversely with relation to the axis of said opening, remote control means on said platform for moving said securing means, the other said pipe being constructed to be received within said opening in said housing in axial alignment therewith, and guide means adjacent the wellhead pipe to guide the conduit pipe into alignment with the wellhead pipe as the said conduit pipe is lowered from the platform and to position the two pipes and said connector with said securing means in transverse alignment with said other pipe so that said other pipe can be engaged by the said securing means.

6. Apparatus for drilling and working in a well submerged under a body of water comprising a platform at the surface of a body of water above a submerged well site, wellhead equipment submerged in said water at said well site, a conduit extending downwardly from said platform through said water to said wellhead equipment, means on said platform for raising and lowering said conduit through said water, a remotely controllable connector for connecting and disconnecting said conduit and said wellhead equipment, said connector comprising a housing secured to the said conduit and having an opening therethrough in axial alignment with said conduit, an elastic sleeve sealed at its ends in said housing and disposed around the housing opening to be movable transversely with relation to the axis of said opening to project inwardly into said open-

ing and to retract outwardly from said opening, operating means to move said sleeve into the opening through the housing, a remote control means on said platform for said operating means, an exterior portion of said submerged wellhead equipment constructed to be received within said opening in said housing in axial alignment therewith, and complementary engaging means on said wellhead equipment and on said connector housing disposed to engage each other in concentric relationship as said conduit is lowered from said platform and to position said connector on said wellhead equipment with said sleeve in transverse alignment with said exterior portion to be disposed against said exterior portion when said sleeve is moved into the opening through the housing.

7. In combination with a well drilling string, apparatus for drilling a well in a formation under water, comprising: a support; a casing positioned in said formation and having its upper end substantially at the surface thereof, said casing being sealingly cemented in said formation; a safety release joint mandrel secured to the upper end of said casing; an anchor device secured to said casing; flexible guides secured to and extending between said anchor and said support; a vertical assembly of series connected drilling devices including a control gate having a gate ram and a safety release joint barrel unit, said unit being matable with said mandrel, said assembly defining a drill pipe passageway and said gate ram being operable into a position closing off said drill pipe passageway; means on said assembly for slidable engagement with said flexible guides; and means including connections and apparatus extending from said support for operating said control gate.

* * * * *

Disclaimer

3,682,243.—*Robert F. Bauer*, Whittier, Calif., *Robert C. McNeill*, Sunset, Utah, and *Jerry T. Ledbetter*, Whittier, Calif. UNDERWATER WELLS. Patent dated Aug. 8, 1972. Disclaimer filed Apr. 7, 1971, by the assignee, *Shell Oil Company*.

Hereby disclaims the portion of the term of the patent subsequent to Jan. 12, 1988.

[*Official Gazette October 16, 1973.*]

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,682,243 Dated August 8, 1972

Inventor(s) ROBERT F. BAUER ET AL

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Title page [60] "Division" should read --Continuation--

Col. 1, line 1, "divisional" should read --continuation--

Col. 9, line 35, "reams" should read --rams--

Col. 11, line 2 "down guide" should read --down over guide--

Col. 11, line 38, "external dog 100" should read --external dog 200--

Col. 14, line 27, "well sit" should read --well site--
Claim 5)

Signed and sealed this 8th day of May 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents