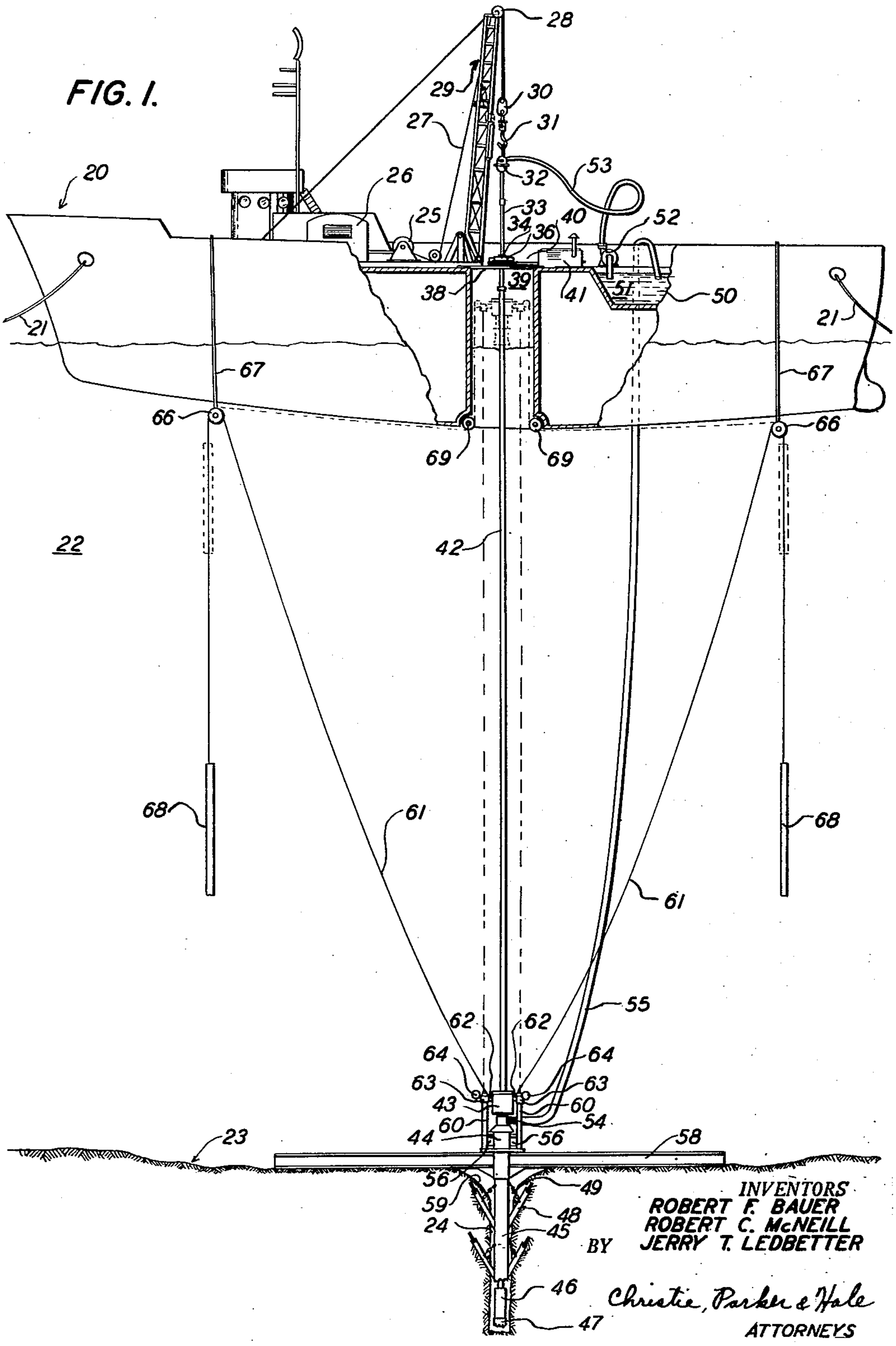
FIG. 1.



INVENTORS
ROBERT F. BAUER
ROBERT C. McNEILL
JERRY T. LEDBETTER

BY Christie, Parker & Hale

ATTORNEYS

FIG. 2.

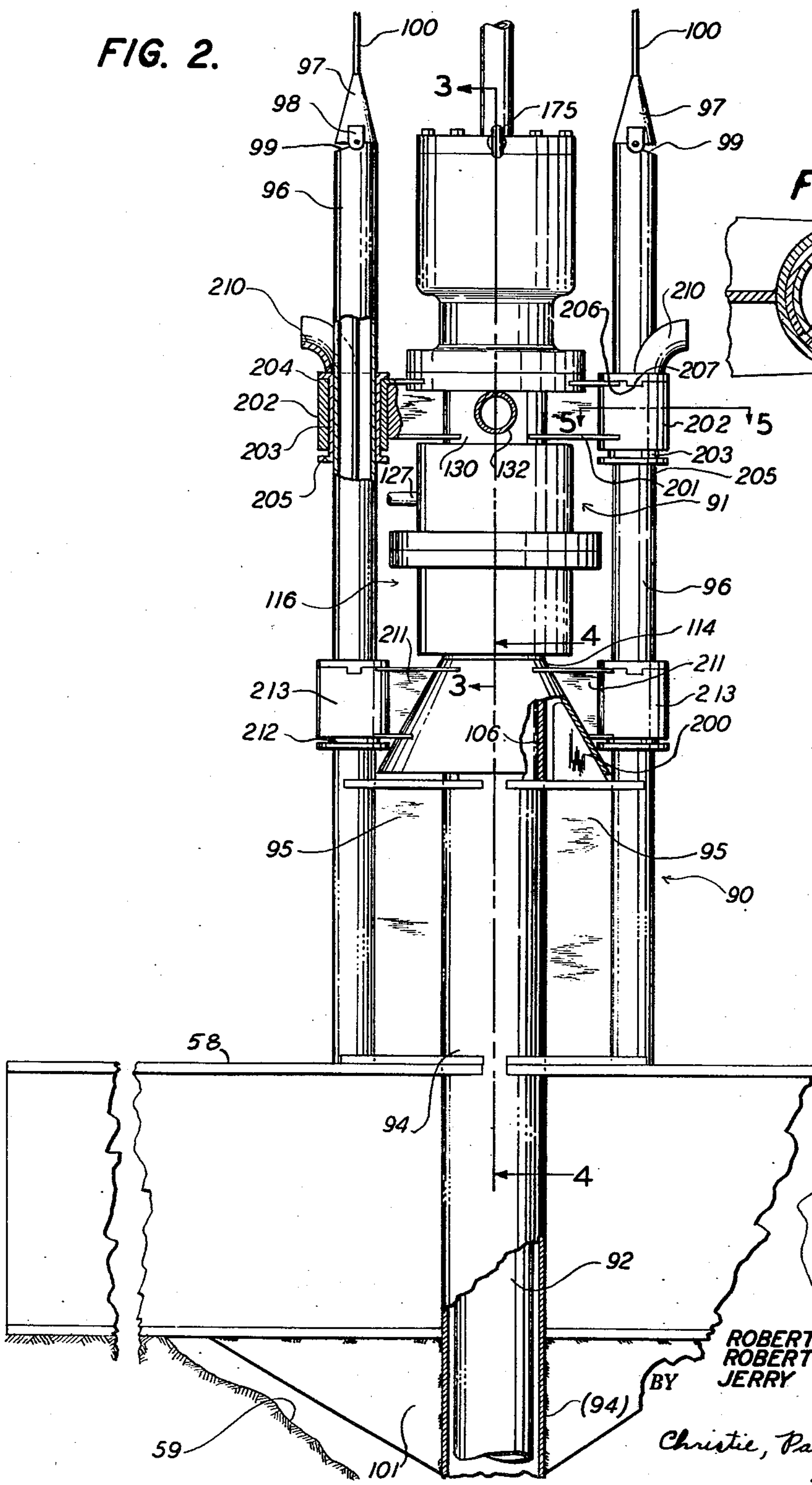
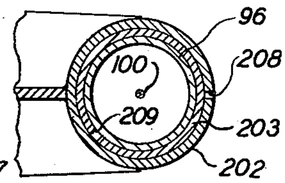


FIG. 5.



INVENTORS
ROBERT F. BAUER
ROBERT C. McNEILL
JERRY T. LEDBETTER

BY Christie, Parker & Hale
ATTORNEYS

OFF-SHORE DRILLING

Filed Nov. 12, 1954 4 Sheets-Sheet 3

FIG. 3.

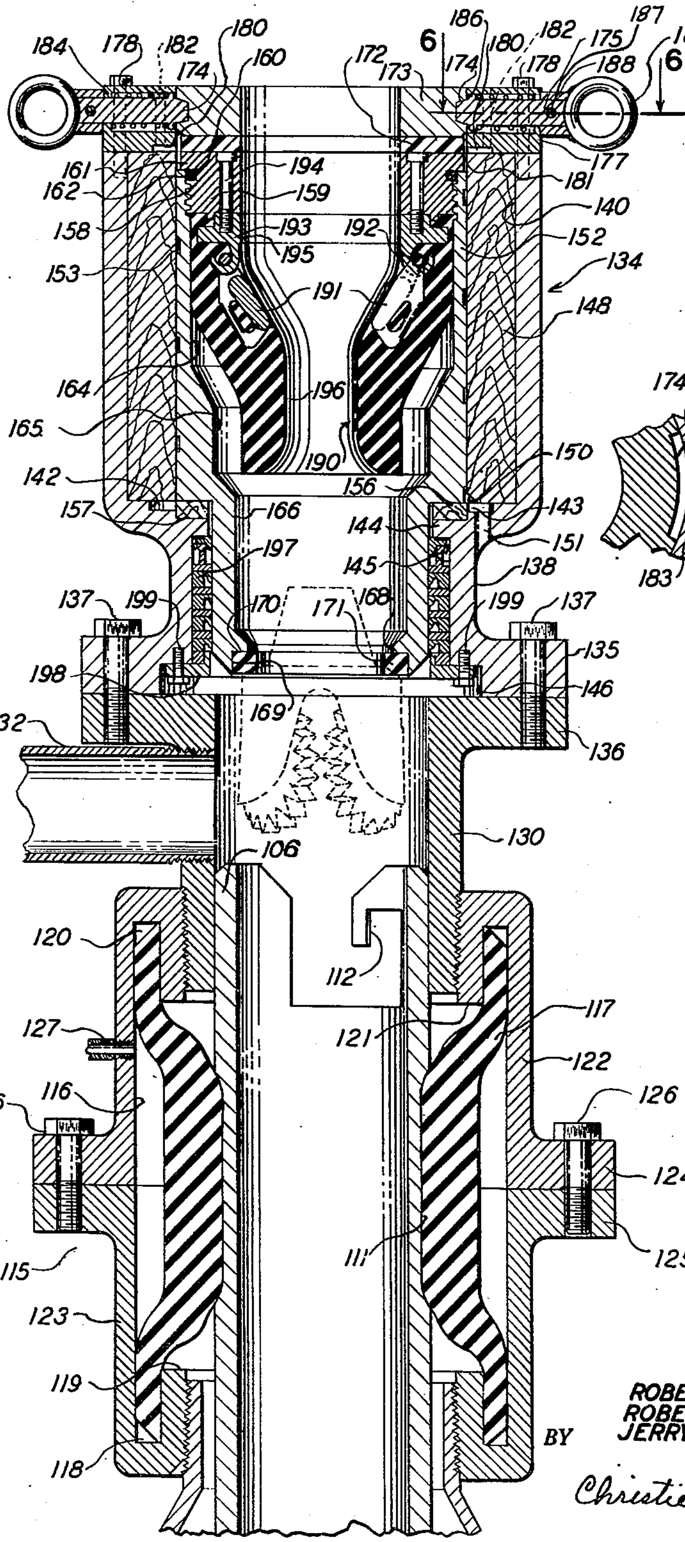
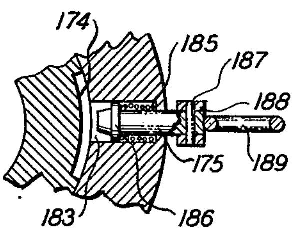


FIG. 6.



INVENTORS
ROBERT F. BAUER
ROBERT C. McNEILL
JERRY T. LEDBETTER
BY
Christie, Parker & Hale
ATTORNEYS

Oct. 1, 1957 R. F. BAUER ET AL 2,808,229

OFF-SHORE DRILLING

Filed Nov. 12, 1954 4 Sheets-Sheet 4

FIG. 4.

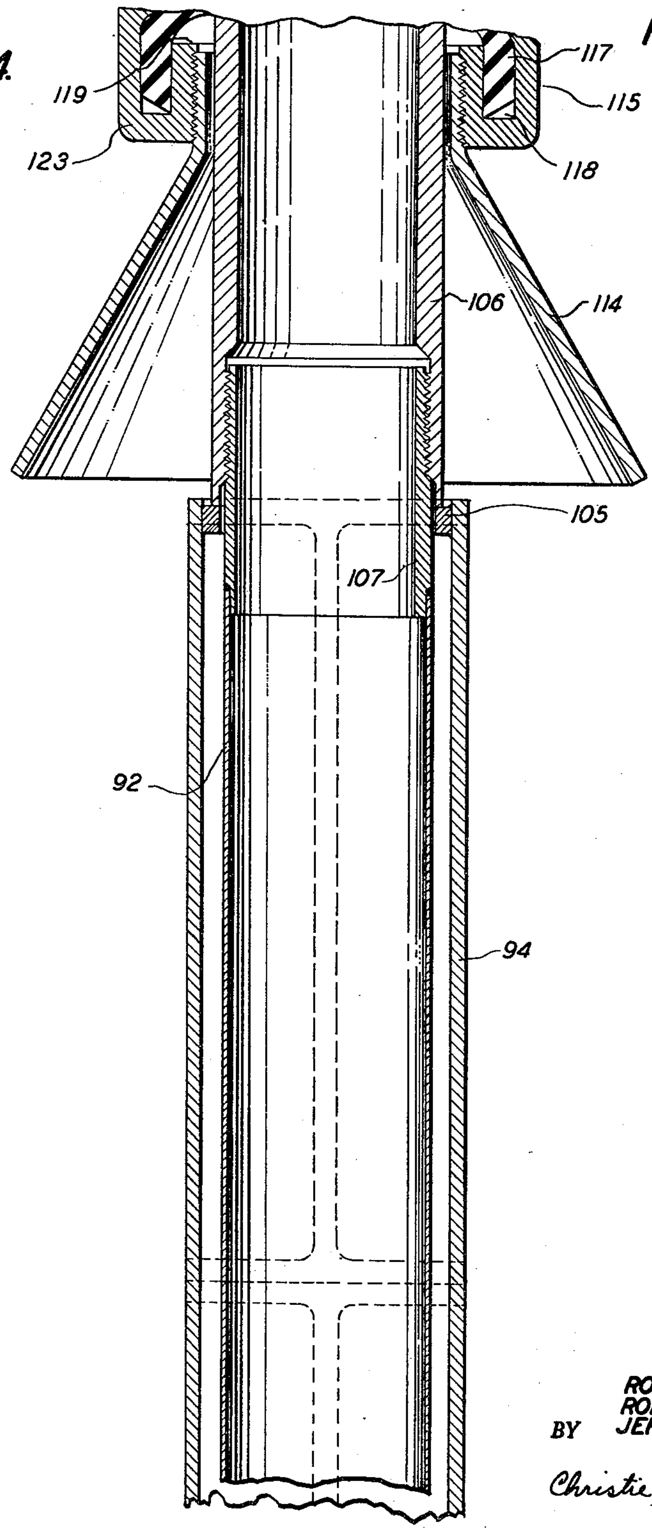
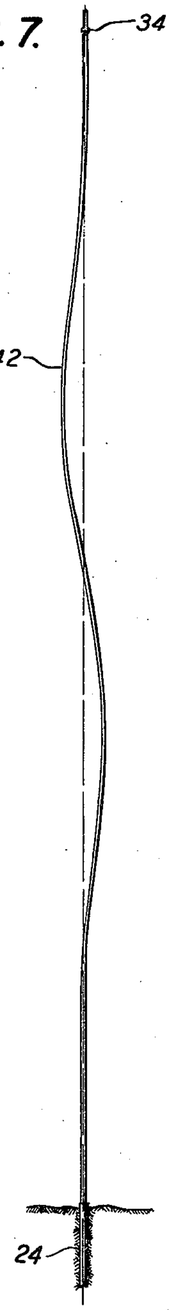


FIG. 7.



INVENTORS
ROBERT F. BAUER
ROBERT C. McNEILL
JERRY T. LEDBETTER

BY Christie, Parker & Hale

ATTORNEYS

United States Patent Office

2,808,229

Patented Oct. 1, 1957

1

2,808,229

OFF-SHORE DRILLING

Robert F. Bauer, Whittier, Robert C. McNeill, Long Beach, and Jerry T. Ledbetter, Whittier, Calif., assignors to Shell Oil Company, Los Angeles, Calif., a corporation of Delaware; Continental Oil Company, Los Angeles, Calif., a corporation of Delaware; The Superior Oil Company, Los Angeles, Calif., a corporation of California, and Union Oil Company of California, Los Angeles, Calif., a corporation of California

Application November 12, 1954, Serial No. 468,214

14 Claims. (Cl. 255—2.5)

This invention relates to apparatus and methods for drilling and working on underwater wells using equipment mounted on a floating vessel.

At the present time, underwater or off-shore well drilling is accomplished from stationary structures rigidly anchored to the underwater formation. These structures provide static bases for the drilling equipment and are satisfactory for relatively shallow water, for example, depths of 50 feet or less. However, for deeper water, for example, depths of several hundred feet, stationary structures are not always economically practical. Furthermore, the structures are sometimes permanent installations which may become navigation hazards.

This invention overcomes the disadvantages of stationary bases for off-shore drilling by providing means for drilling wells from a floating vessel which can readily be moved from one location to another, and which can be used in water of practically unlimited depth. In addition, the wells so drilled may be completed on the ocean floor so as not to create a hazard to navigation.

The principal difficulty in drilling or working on an underwater well from a floating vessel is in making trips in and out of the well, i. e., withdrawing drilling or other equipment from the well and subsequently re-entering the well with such equipment. The movement of a floating vessel due to wind, current and wave action which is almost invariably present makes it difficult to re-locate the well once equipment is removed from it. Another difficulty in off-shore drilling from a floating vessel is the establishment of a return circulation system, i. e., a system in which a drilling fluid may be pumped down the center of a drill pipe, out the end of a drill bit on the lower end of the drill pipe, up the annular space between the well and the drill pipe, and back to the surface where drill cuttings can be removed and the drilling fluid used again for re-circulation.

The present invention overcomes these problems by providing apparatus which facilitates making trips in and out of the well with equipment, and also for obtaining return circulation.

Briefly, the invention contemplates apparatus for guiding equipment in and out of a well in a formation underlying water. The apparatus comprises an anchor member disposed at the upper end of a well bore and anchored to the formation, and an elongated guide member attached to the anchoring member. The guide member extends toward the surface of the water and is used to guide equipment in and out of the well.

In a preferred form, the anchoring member is a conductor casing or conduit anchored in the upper end of the well. The lower ends of two guide cables extending toward the water surface are attached to the upper end of the conduit at diametrically opposed points and serve to guide equipment in and out of the well. The equipment which is moved in and out of the well is carried by brackets adapted to slide up and down the cables, the upper ends of which are supported by a vessel floating above the well.

2

The invention provides means for obtaining return circulation by using a receiver assembly attached to the upper end of the conduit. The receiver assembly makes a fluid-tight seal with the conduit and is provided with a central opening in alignment with the conduit. A circulating head adapted to lock releasably to the receiver and form a fluid-tight seal therewith is arranged to seal around a drill pipe rotatably disposed through the circulating head, the opening in the receiver unit and the conduit. Means are provided for conducting the drilling fluid from the annular space between the drill pipe and the well to the water surface.

Another difficulty with drilling from a floating vessel is maintaining the drill bit in constant contact with the formation as the well is drilled and in maintaining a substantially constant pressure on the drill bit because the vertical motion imparted to the floating vessel due to wave action tends to raise and lower the bit as the well is drilled.

The invention overcomes this difficulty by providing a drilling method which compensates for the wave action and maintains the drill bit in contact with the formation continuously and with a substantially constant pressure. In terms of method the invention comprises drilling an underwater well in formation with a bit attached to the lower end of a drill pipe supported by a vessel floating in water by restraining the lateral motion of the drill pipe near the upper end of the well and applying torque to the drill pipe at a substantial distance from the upper end of the well so that the drill pipe rotates and becomes deformed. Depending upon the nature of the drill pipe the distance between the upper end of the well and the point on the drill pipe to which torque is applied, the speed of rotation of the drill pipe, the total amount of drill used, and the amount of weight of the drill pipe supported by the vessel, the degree of drill pipe deformity can be controlled within a wide range. Care is taken not to exceed the elastic limit of the drill pipe so that it is not permanently deformed or damaged. Thus, the deformed drill pipe acts as an elongated spring and accommodates the change in position of the floating vessel due to wave action.

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

Fig. 1 is a schematic elevation of an underwater drilling operation being conducted from a floating vessel;

Fig. 2 is an elevation, partly in section, of the upper end of a conductor casing set in an underwater formation with a receiver assembly and drilling head mounted thereon in sealed relationship for drilling;

Fig. 3 is a view taken on line 3—3 of Fig. 2;

Fig. 4 is a view taken on line 4—4 of Fig. 2;

Fig. 5 is a view taken on line 5—5 of Fig. 2;

Fig. 6 is a view taken on line 6—6 of Fig. 3; and

Fig. 7 is a schematic elevation of the drill pipe of Fig. 1 elastically deformed during drilling.

Referring to Fig. 1 a floating vessel such as a ship **20** is anchored by means of anchor lines **21** in a body of water **22** over a formation **23** in which a well **24** is to be drilled. A draw-works **25** and power unit **26** which may be of conventional type are mounted on the ship to operate a hoisting cable **27** carried over a crown block **28** located at the upper end of a collapsible drilling rig **29**. The traveling end of the hoisting cable carries a traveling block **30** and a hook **31** which supports a swivel joint **32**. A Kelly joint **33** extends downwardly from the swivel through a Kelly bushing **34** in the center of a rotary table **36** mounted on gimbals in a manner such as that described in U. S. Patent 2,606,003. The rotary table is supported by a platform **38** directly over a cellar **39** which may be located in the center of the ship, as illustrated. Power is supplied to the rotary table through a shaft **40** turned by a rotary table power unit **41**.

A string of drill pipe **42** is connected to the lower end of the kelly and extends down through the cellar, the water, and into the well through a pressure circulating head **43** which is releasably sealed to a receiver assembly **44** attached to the upper end of a conductor casing or conduit **45** coaxially disposed within, and providing support for the upper portion of the well. A drill collar **46** and a drill bit **47** are attached to the lower end of the drill pipe for boring the well to the required depth. A plurality of outwardly and upwardly extending flukes **48** hinged on the casing serve to anchor the conduit firmly in the formation. Each fluke is provided with a chain **49** having one end attached to an intermediate portion of its respective fluke, and having the other end attached to the casing above the hinge connection. The casing may be cemented in place and the flukes omitted.

The pressure circulating head and the receiver assembly may take a variety of forms, a specific example of which is described in detail below. Generally speaking, however, the receiver assembly is provided with a central opening and is releasably sealed to the upper end of the conduit **45**. The pressure circulating head is adapted to seal releasably to the receiver assembly and is also provided with a central opening through which the drill pipe is rotatably sealed. Thus, the pressure circulating head and the receiver assembly cooperate to form a seal between the rotatable drill pipe and the conduit. This permits a drilling fluid or mud **50** to be circulated from a mud tank or pit **51** in the ship by a mud pump **52** through a drilling mud hose **53** to the swivel, down through a central opening (not shown) in the kelly, drill pipe, and drill collar, out the passages in the bit, up the annular space between the drill pipe and the well wall, out a drilling mud return nipple **54** located in the circulating head, and up a flexible drilling mud return hose **55** extending from the nipple to the mud pit.

A pair of relatively short horizontal yoke arms **56** are attached on diametrically opposed sides of the upper end of the surface casing or conductor and extend radially outwardly. Conveniently the arms are made of heavy I beams. A pair of elongated support arms **58** are attached to the casing under the yoke arms and extend outwardly a substantial distance from the well. The support arms span a crater **59** which is sometimes formed at the upper end of the well, and prevent the receiver assembly from sinking below the level of the ocean floor prior to the anchoring of the casing in its final position. A separate hollow vertical guide post **60** is rigidly attached to the outer end of each yoke arm and extends above the upper end of the casing **45**. A separate guide cable or line **61** is attached to the lower end of each guide post and extends up through the guide post and out of the upper end thereof.

A pair of radially extending brackets **62** are rigidly attached to diametrically opposed points on the circulating head which is periodically lowered to and raised from sealing relationship with the receiver assembly. A separate vertically extending cylindrical sleeve **63** is attached to the outer end of each bracket. The sleeves are adapted to slide along the cables over the upper ends of the guide posts to assure proper sealing alignment of the circulating head with the receiver assembly. Each sleeve has a guide cable traveling pulley **64** which reduces the wear of the guide cables as the sleeves travel up and down the cables.

With the circulating head sealed to the receiver assembly, the positions of the guide cables are as shown by the solid lines in Fig. 1, i. e., each cable extends upwardly and outwardly from the casing over separate support pulleys **66** carried by the lower portions of two separate bridles **67** supported at the forward and rear portions of the ship bottom respectively. Each cable then extends downwardly and is attached to a freely hanging and adjustable weight **68**. The weights serve to maintain a constant tension on the guide cables even though the ship is raised and lowered by wave action.

When the circulating head is released and withdrawn from the receiver assembly up into the cellar, the position of the guide cables is as shown by the dotted lines of Fig. 1, i. e., each cable extends upwardly into the cellar, over its respective traveling pulley, around a protective pulley or roller **69** located at the lower edge of the cellar and then along the keel of the ship to its respective supporting pulley. The position of the weights and the circulating head at the surface is also shown in dotted lines.

With a conductor casing located as illustrated in Fig. 1, a well is drilled in the following manner. The circulating head is supported in its upper or dotted line position under the rotary table by suitable releasable hooks (not shown). The drill collar is lowered through the circulating head and then the drilling bit is secured to the lower end of the drill collar. The drill bit is of sufficient diameter to engage an internal shoulder (not shown in Fig. 1) within the circulating head and provides support therefor so that the bit is "shrouded" by the circulating head. The circulating head is then released from the rotary table and lowered as additional drill pipe is coupled to and above the drill collar. After the required length of drill pipe is coupled, the circulating head is in the lower position shown in Fig. 1 and sealed to the receiver assembly in a manner described below. The "shrouding" of the bit by the circulating head insures alignment of the drill bit and collar with the conductor casing and reduces the possibility of the equipment at the upper end of the casing being damaged by direct contact with the heavy drill bit, collar and pipe due to the wave action on the ship.

Additional drill pipe is added to permit the drill bit to be lowered to the bottom of the well. The Kelly joint is then attached to the upper end of the drill pipe and is rotated by the rotary table. With the circulating head sealed to the receiver assembly, the guide cables are now in the solid line positions shown in Fig. 1. That is, they are carried well away from the drill pipe. This reduces the danger of the drill pipe becoming fouled with the guide cables.

The gimbal mounting of the rotary table permits the rotary table to remain in a horizontal position even though the ship is pitched and rolled by wave action. The effect of the vertical movement of the ship is minimized by using the centrifugal force of the drill pipe to deform the pipe into a temporary bow or a plurality of bows (see Fig. 7) in the drill pipe between the ship and the ocean floor. The desired deformation of the drill pipe is achieved as follows: With the drill pipe shown as illustrated in Fig. 1, i. e., with the drill bit slightly off the bottom of the hole and the Kelly joint attached to the upper end of the drill pipe and extending through the rotary table, the drill pipe is rotated. The centrifugal action of the drill pipe causes it to "bow" or deform to approximately the shape shown schematically in Fig. 7. While continuing the rotation of the drill pipe so that the deformed configuration is maintained, the pipe is gradually lowered by means of the hoisting cable until the bit contacts the bottom of the well. Additional slack is payed out on the hoisting cable until the desired bit pressure is achieved. Care is taken to avoid rotating the drill pipe at an excessive rate or applying an excessive pressure to the drill bit to prevent permanent deformation of the drill pipe. Thus, the drill pipe between the well head and the rotary table is deformed to form what is effectively an elongated spring which compensates for the up-and-down motion of the ship. As a result, vertical motion of the ship produces a relatively small change in the pressure with which the bit bears against the bottom of the well. This method of drilling is made possible by the fact that drill pipe is not restrained against lateral movement by a casing or a well bore or the like for a substantial distance, e. g., the distance from the ocean floor to the ocean surface. Therefore, while the method is satisfactory for water depths as little as 30', it becomes increasingly advantageous as the water depth increases. The vertical motion of the ship may also be compensated for by the use of a long-stroke hydraulic tool of a type which is used in on-shore drilling for applying a constant force to a drilling bit, or by using an expansion joint in the drill string immediately above the drill collars.

With the drill bit on the bottom of the well, power is applied to the rotary table to rotate the bit, and drilling mud is pumped down through the bit from the mud pit. As cuttings are formed in the well, they are carried by the mud up the annular space between the drill pipe and the well, out the drilling fluid return nipple, up the return line and dumped into the mud pit to settle out. Drilling is continued until such time as it is necessary to withdraw the bit from the well, e. g., to set additional casing or change the drill bit.

To remove the drill pipe and bit from the well, the circulating head is released from the receiver assembly and the hoisting cable is operated to raise the drill pipe until the drill collar or drill bit engages the internal shoulder within the circulating head from the receiver assembly so that it is carried to the upper position shown by dotted lines in Fig. 1. One method for sealing the circulating head to and releasing it from the receiver unit is described below in connnection with the apparatus illustrated in Figs. 2–6.

The foregoing description presents the overall procedure of underwater drilling from a floating vessel. However, before the drilling can be accomplished, the conductor casing or conduit which makes it possible to guide equipment in and out of the well must be properly located in the formation. The conductor casing may be set or anchored in numerous ways such as that described in co-pending application Serial Number 477,807, filed December 27, 1954.

Figs. 2 through 6 show one form of a receiver assembly **90** and a circulating head **91** which are attached to the upper end of a conductor casing or conduit **92** anchored co-axially in the upper end of the well **24** (see Fig. 1) to permit underwater drilling in the manner described above. Apparatus of the type shown in Figs. 2 through 6 is described in detail and claimed in co-pending application Serial Number 482,206 filed January 17, 1955.

Referring to Figs. 2 through 6, the receiver assembly (see Figs. 2 and 4) comprises an upright sleeve **94** to the upper end of which is welded a pair of diametrically opposed and radially extending I beams or yoke arms **95**. The flanges of the I beams are horizontal. A separate upright cylindrical and hollow guide post **96** is welded in a matching notch formed at the outer end of each yoke arm. Each guide post extends from the bottom of the yoke arm to a substantial distance above the arm. A separate hollow upright cone **97** is pivotally attached by pins **98** to the upper end of each guide post. The outer portion of the upper end of each guide post is beveled downwardly at **99** to permit the upper end of the cones to pivot outwardly. A separate guide cable **100** is anchored by suitable means (not shown) to the lower end of the guide posts and extends up through its respective guide post and cone to have its upper end supported from the floating vessel as described with Fig. 1. The pivotable cone reduces the wear on the cable during the raising and lowering of the circulating head.

A pair of elongated support arms **58** are attached to the sleeve under the yoke arms and extend outwardly a substantial distance from the well. The support arms span a crater **59** which is sometimes formed at the upper end of the well, and prevent the receiver assembly from sinking below the level of the ocean floor prior to the anchoring of the casing in its final position. A pair of reinforcing gussets **101** are welded to the support arms and the sleeve for added strength.

An internal supporting ring **105** (see Fig. 4) is welded within the upper end of the sleeve and provides support for the lower end of a cylindrical mandrel **106** into which is screwed the upper end of casing coupling **107**. The upper end of the conductor casing or conduit **92** is welded to the lower end of the casing coupling. The casing extends coaxially into the well drilled into a formation **110**. The mandrel extends co-linearly above the sleeve and is provided with an annular external notch **111** near its upper end (see Fig. 3). A J notch **112** is provided in the upper edge of the mandrel which is used in conjunction with a suitable J tool (not shown) to raise and lower the casing attached to the mandrel and to unscrew the mandrel from the casing coupling in the event the well is abandoned.

The circulating head comprises a frusto-conical shell **114** (see Fig. 4) having its upper end screwed into the internally threaded lower end of a cylindrical mandrel seal housing **115** (see Fig. 3) which is provided with a bore **116** of increased diameter in its intermediate portion and adjacent the external annular groove on the mandrel. The lower end of an annular flexible mandrel seal **117** is friction fitted into an upwardly opening annular channel **118** in the upper surface of an internal annular shoulder **119** formed in the lower end of the mandrel seal housing. The upper end of the mandrel seal is friction fitted into a downwardly opening annular channel **120** in the lower surface of an annular internal shoulder **121** formed in the upper end of the mandrel seal housing. Conveniently, the mandrel seal housing is formed in an upper half **122** and a lower half **123**, each half being provided with a matching annular and outwardly turned flange **124**, **125** respectively at their inner ends. The two halves are held together by means of bolts **126**. A sealing nipple **127** is threadably engaged through the wall of the upper half of the sealing mandrel so that hydraulic pressure may be applied to the mandrel seal and force it to form a fluid-tight seal in the external notch of the mandrel. This also provides positive gripping means by which the circulating head is held down on the mandrel. The lower end of a conduit **130** is screwed into the upper end of the mandrel seal housing. One end of a drilling mud return nipple **132** is threaded through the conduit wall. The other end of the nipple is connected to a flexible drilling mud return line (not shown) which extends to the surface.

A drill pipe seal housing or body **134** (Fig. 3) having an outwardly turned flange **135** at its lower end is secured to an outwardly turned flange **136** at the upper end of the conduit by means of bolts **137**. The external diameter of the body is approximately the same as that of the mandrel seal housing; however, the body external diameter is reduced at **138** just above the body flange. The body is provided with a relatively large first internal bore **140** which extends from the upper end of the body down near the portion of the housing which is of reduced external diameter. The bore is then stepped down to a smaller second bore **142** for a short distance, then is stepped down to a third bore **143** for a short distance, then is stepped down to a fourth bore **144** for a short distance, then stepped up to a fifth bore **145** slightly less than that of the third bore to extend to a point near the lower end of the body, and is then stepped up to a larger sixth bore **146** which extends to the lower end of the body.

A sleeve bearing **148** which may be lignum vitae, for example, is disposed within the large bore at the upper end of the body, the lower end of the bearing resting on the shoulder formed at the end of the first bore and its upper end being flush with the upper end of the body. The inner diameter of the sleeve bearing is less than that of the second bore. The inner edge of the lower end of the annular sleeve bearing **148** is beveled at **150** to permit water to flow up through a lubricating inlet port **151** provided in the horizontal section of the body wall above the reduced external diameter of the body. A metal insert **152** having an external diameter at its upper end slightly less than the internal diameter of the sleeve bearing is rotatably disposed within the sleeve bearing so that the upper end of the insert is below that of the bearing. An external spiral groove **153** in the insert wall permits water to be circulated by convection and friction up from the lubricating inlet port to keep the insert cool and lubricated during rotation.

The external diameter of the insert is stepped down to a reduced diameter at the same location where the first bore of the body is stepped down to a reduced diameter. This forms an external shoulder **156** on the insert which rests on a thrust ring bearing **157** carried in the shoulder formed between the third and the fourth bores of the body. The upper end of the insert is internally threaded at **158** to receive a threaded bushing **159** which has an annular external groove **160** near its upper end and an outwardly turned flange **161** which rests on the upper edge of the insert. An O ring **162** in the annular groove effects a fluid tight seal between the bushing and the insert.

The insert **152** is provided with a relatively large internal first bore **164** at its upper end which tapers to a reduced second bore **165** near its intermediate portion, then tapers again to a reduced third bore **166** in its lower portion, tapers again to a reduced fourth bore **168** and then steps out to an increased fifth bore **169** to provide a lifting shoulder **170** on which there is disposed a cushion ring **171** which may be made of heavy rubber. An upper thrust ring bearing **172**, which may be of micarta (a phenolic plastic), is disposed on the upper end of the bushing and supports a retaining ring **173** provided with a pair of diametrically opposed slots **174** in its periphery, each slot being adapted to receive a longitudinally movable locking pin **175**. A fastening ring **177** is disposed on top of the upper ends of the sleeve bearing and the body wall and is rigidly attached to the body wall by means of bolts **178**. The inner periphery of the underside of the fastening ring is provided with a groove **180** which communicates with an annular space **181** formed between the upper thrust ring bearing, the upper end of the bushing, the fastening ring and the sleeve bearing. A plurality of vertical lubricating outlet ports **182** in the fastening ring connect with the groove **180** and permit the lubricating water to flow from the interior of the body **134**.

A pair of horizontal bores **183** through the fastening ring house the locking pins. The bores are of reduced diameter at their outer ends to form a shoulder **184**. A compression spring **185** is co-axially disposed around each locking pin and bears against a flange **186** attached to the inner end of each locking pin and bears against the shoulder of the locking pin bores. The outer ends of the locking pins extend out beyond the fastening ring and are each provided with a transverse pin **187** which holds a stop collar **188** around the outer end of each locking pin. A ring handle **189** is welded to the outer end of each stop collar to facilitate its operation.

An annular flexible drill pipe seal **190** is co-axially disposed within the insert and is supported at its upper end by a plurality of metal "eyes" **191** molded into the seal and held by corresponding hooks **192** formed integrally on a seal ring **193** secured to the underside of the bushing by means of bolts **194**. The drill pipe seal has a relatively large first bore **195** at its upper end and tapers to a reduced second bore **196** at its lower end, and is sufficiently flexible to be expandable to a large enough diameter to permit the passage of drill pipe and drill collars. However, under ordinary drilling operations, the seal clamps tightly around the drill pipe or drill pipe joints so as to rotate with the pipe and effect a fluid type seal.

An insert seal **197** is disposed in the annular space formed between the lower end of the insert **152** and the fifth internal bore **145** of the body. The insert seal is held up in position by means of an insert seal retaining ring **198** secured by means of bolts **199** to the shoulder formed between the fifth and sixth internal bores of the body.

Referring to Fig. 2 a pair of radially extending and diametrically opposed upright lugs **200** in the shape of right triangles are welded to the intermediate portion of the upper flanges of the I beams and directly over the webs of the I beams. The longest sides of the lugs engage the inner surface of the shell attached to the lower end of the circulating head and thus insure proper alignment of the mandrel seal with the external notch in the mandrel.

An upper pair of diametrically opposed and radially extending brackets **201** (preferably short sections of small I beams) are welded to the external surface of the conduit **130** on the circulating head to extend outwardly and horizontally. A separate vertical outer sleeve **202** is welded to the outer end of each of the upper brackets. A separate rotatable inner sleeve **203** is disposed within each outer sleeve and is slightly longer than the outer sleeve. An upper retaining ring **204** and a lower retaining ring **205** are attached to the upper and lower ends respectively of each inner sleeve to limit the vertical travel of the inner sleeve within the outer sleeve. The upper edge of each outer sleeve is notched at **206** to accommodate a downwardly extending projection **207** provided on the lower side of each upper retaining ring on the inner sleeve. Each outer sleeve is provided with a vertical slot **208** extending for the length of the outer sleeve and through the outermost portion of the outer sleeve wall. A matching slot **209** is provided in each inner sleeve, the inner sleeve slot being located so that the two slots are out of register when the upper ring projection is seated in the notch in the outer sleeve. Thus, the inner sleeve can be lifted and rotated to bring the two slots into register. In this position the guide cables are slipped into the interior of the inner sleeve. The outer sleeve is then rotated until the projection seats in the notch. Positive springing means may be provided to insure that the two slots are maintained out of register during the operation of the equipment. An upwardly and outwardly extending horn **210** having a concave upper surface is welded to the upper retaining ring and serves the dual function of a handle for rotating the inner sleeves and for reducing the wear on its respective guide cable as the circulating head is raised and lowered.

A similar pair of lower guide brackets **211** and inner and outer sleeves **212**, **213** respectively, are attached to the external surface of the shell, the principal difference being that no horns are provided on the upper retaining rings of the lower pair of brackets.

With the conductor casing and the receiver assembly anchored in the formation, and the upper end of the guide cables suspended over the supporting pulleys carried by the floating vessel as indicated schematically in Fig. 1, the operation of the circulating head and receiver assembly illustrated in Figs. 2 through 6 is as follows: the circulating head is suspended underneath the rotary drilling table by suitable hooks (not shown) and the locking pins are pulled out so that the retaining ring, the insert and its associated parts can be removed from the interior of the circulating head body. The drill collars are then lowered until the lower end of the drill collars project below the circulating head. The drill bit is screwed onto the lower end of the drill collars, and the insert and retaining ring are slipped down over the drill collars into position with the circulating head body. The locking pins are allowed to move inwardly and lock the retaining ring in position.

The circulating head is then lowered until the internal cushion gasket **171** seats on the upper edge of the drill bit (shown in dotted lines in Fig. 3). Thus, the lower portion of the circulating head shrouds the bit. The drill collars, drill bit and circulating head are lowered as additional drill collars and drill pipe are coupled above the drill collars. When sufficient drill pipe is coupled so that the total length of drill pipe and drill collars approximates the water depth in which the vessel is floating, the sleeves on the guide brackets slip down over the guide posts and insure accurate alignment of the circulating head and the receiver assembly, thus preventing the heavy load of drill bit, collars and drill pipe from directly contacting the receiver assembly or the guide posts. This prevents inadvertent damage to these latter elements due to the motion of the ship in the water. The conical shell on the lower end of the circulating head, which is an additional guarantee of correct alignment, seats on the lugs so that the circulating head is positioned with the mandrel seal directly opposite the external groove in the mandrel. Hydraulic pressure is then applied from the surface to the mandrel seal through the pressure nipple in the mandrel seal housing to lock and seal the circulating head to the receiver assembly. Additional drill pipe is coupled at the surface until the drill bit reaches the bottom of the well.

The Kelly joint is then coupled to the upper end of the drill pipe and drilling proceeds as described above. Mud is circulated down the drill pipe, out the drill bit, up the annular space between the drill pipe and the well, out the mud return nipple, and up the mud return hose for recirculating. The hydraulic pressure applied to the mandrel seal is between 500 and 600 pounds per square inch in excess of the drilling mud pressure adjacent the mandrel seal. This not only prevents leakage of the drilling mud but provides a positive grip for the circulating head on the receiver unit and prevents the circulating head from being blown upwardly by the drilling mud pressure. The drill pipe seal maintains a fluid type seal between the circulating head body and the rotating drill pipe. The insert within the circulating head body rotates during the drilling operation and is cooled by the circulating of water up the spiral groove and around the exterior of the insert. The water is drawn in the lubricating inlet port by both convection and frictional forces, passes up the spiral groove, and leaves the circulating head through the lubricating water exit ports.

When the drill pipe is to be withdrawn from the well, for example, to change the bit, circulation of the drilling mud is stopped and the hydraulic pressure on the mandrel seal is released. The drill pipe is then raised by the hoisting cable and draw works until the drill bit engages the internal cushion ring **171** on the insert and raises the circulating head to the surface. Re-entry of the equipment into the well bore is easily accomplished in the manner previously described.

The drilling is then carried to the required depth, additional casing being set within the original surface conduit as required. A receiving assembly similar to that described above may be used at the upper end of each additional string of casing used, and conventional blow-out preventors may be employed for safety.

In extremely rough weather or high seas, it may be desirable to discontinue drilling operations temporarily. In fact, conditions may be such as to warrant the removal of the drilling boat to a harbor. The procedure followed to cope with either eventuality is to remove from the drill string an amount of drill pipe slightly in excess of the depth of the water, plug the top of the string with a tool that coincidently affords a landing seat, and finally, lower the remaining drill string into the well with the landing seat attached, resting on the top of the circulating head. Landing the drill string on the circulating head may be accomplished in several ways; the simplest being to use a hook and bail arrangement, with the hook attached to a utility traveling block of the single sheave, two-line type, strung with sufficient line to permit lowering the whole assembly into the water. Another method is to use the drill pipe in conjunction with a conventional type landing tool. If time permits, it is desirable to remove all of the drill pipe from the hole, actuate the blowout preventer if included, disconnect the return circulation hose, buoy all lines and cast off. The ship would then be free to return to the harbor.

In the event that it is found desirable to produce from a well drilled, as described above, the following procedure may be used to accomplish this objective: Conventional completion practices are followed to the point of installing the Xmas tree. At the point the Xmas tree is made up on a string of tubing and the latter run into the final string of casing using the guide means of this invention. The bottom of the Xmas tree is equipped with a suitable device which permits it to be attached to the casing and establish a pressure-tight seal. Adaptations of conventional tools may be used for this purpose, e. g., a slip-set packer or a pack-off socket. The former attaches Xmas tree to the casing internally and the latter externally. It is also possible to screw the Xmas tree assembly to the casing in threads provided for that purpose. In this event a connecting joint is incorporated in the casing string at the time it is run. At the time the Xmas tree is run, flexible flow lines such as high pressure hose is attached to the Xmas tree. The flexible flow lines are subsequently attached to gathering lines extending from shore, or to a common producing island or to a floating tanker. Thus, a well drilled and completed in accordance with this invention will be submerged well below the water surface.

We claim:

1. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying a body of water comprising in combination a floating vessel, a well head base and means adapted to firmly maintain the base at the formation adjacent the hole, a laterally flexible elongated guide means connected to and extending between the base and vessel so as to permit lateral displacement of the vessel during such operations, a pipe string supported at and extending from the vessel exteriorly of the flexible guide means, connecting means slidably interconnecting the depending end of the pipe string and the guide means so that as the pipe string is lowered it is constrained by the guide means to register the lower end of the string with the upper end of the hole.

2. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying a body of water comprising in combination a floating vessel, a drilling base and means adapted to firmly maintain the base at the formation adjacent the hole, a laterally flexible elongated guide means connected to and extending between the base and vessel so as to permit lateral displacement of the vessel during drilling, a drill string supported at and extending from the vessel exteriorly of the guide means, connecting means slidably interconnecting the depending end of the drill string and the guide means so that as the drill string is lowered it is constrained to register the lower end of the drill string with the upper end of the hole.

3. Apparatus according to claim 2 wherein the drilling base comprises a rigid frame adapted to rest on the bottom and the means to firmly secure the base to the formation comprises an elongated tubular pipe attached adjacent one end to the base and extending downwardly therefrom for projection into the formation to define the upper end of the hole.

4. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying a body of water comprising in combination a floating vessel, a drilling base and means adapted to firmly secure the base to the formation adjacent the hole, a flexible guide cable fastened to the base at a point spaced laterally from the hole and extending between the base and vessel so as to permit lateral displacement of the vessel during drilling, a drill string supported at and extending from the vessel, connecting means slidably interconnecting the depending

end of the drill string and the guide cable, the connecting means holding the lower end of the drill string a fixed distance from the guide cable so that as the drill pipe is lowered it is constrained by the guide cable to register with the upper end of the hole.

5. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying a body of water comprising in combination a floating vessel, a base framework adapted to rest on the bottom, means adapted to firmly secure the base to the formation adjacent the upper end of the hole, a pair of flexible guide cables fastened to the base at spaced points laterally spaced from the upper end of the hole and extending between the base and vessel to permit lateral displacement of the vessel with respect to the base during drilling, a drill string supported at and extending from the vessel, connecting means slidably interconnecting the depending end of the drill string and the guide cables so that as the drill string is lowered it is constrained by the guide cables to register with and enter the upper end of the hole.

6. Apparatus according to claim 5 wherein the base framework is provided with a pair of vertically extending posts laterally spaced from opposite sides of the hole, the guide cables are respectively fastened to extend upwardly from the upper ends of the posts, and the connecting means includes means for engaging the posts as it reaches the lower extremity of the guide cables.

7. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying a body of water comprising in combination a floating vessel, tension means for anchoring the vessel, a base framework adapted to rest on the bottom, an elongated conductor pipe attached adjacent one end to the base framework and extending downwardly from the base framework into the hole to anchor the base framework to the formation, a laterally flexible elongated guide means fastened to the base framework laterally of the conductor pipe and extending between the base framework and vessel so as to permit lateral displacement of the vessel during drilling, a drill string supported at and depending from the vessel, a drilling tool supported on the lower end of the drill string, a circulating head slidably mounted on the drill string, and connecting means interconnecting the circulating head and guide means so that as the circulating head is lowered with the drill string it is constrained by the guide means to register with the conductor pipe and automatically cause the drill tool as the drill string is further lowered to enter the conductor pipe.

8. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying water comprising in combination a floating vessel, a well on the vessel giving access to the water and located approximately symmetrically about the center line of the vessel, a platform overlying the well and spaced above the water to leave a basement between the platform and water, a rotary table supported by the platform, a well head base including means adapted to firmly secure the base to the formation adjacent the hole, flexible elongated guide means connected to and extending between the base and the vessel, means on the vessel for supporting and extending a pipe string downwardly through the well exteriorly of the guide means, connecting means slidably interconnecting the depending end of the pipe string and the guide means so that as the pipe string is extended downwardly from the well its lower end is constrained by the guide means to enter the hole.

9. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying water comprising in combination a floating vessel, a well on the vessel giving access to the water and located approximately symmetrically about the center line of the vessel, a platform overlying the well and spaced above the water to leave a basement between the platform and water, a rotary table supported by the platform, a drill rig mounted on the vessel for supporting a drill string to extend through the rotary table, a drilling base including means adapted to firmly secure the base to the formation adjacent the hole, an elongated guide cable laterally spaced from the hole connected to and extending from the drilling base to the vessel, and means for slidably interconnecting the lower end of the drill string with the guide cable whereby well head and drilling equipment can be supported by the drill string and can be lowered form the vessel to the base by lowering the drill string while the lower end of the drill string is constrained by the guide means to enter the hole.

10. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying water comprising in combination a floating vessel, a well on the vessel giving access to the water and located approximately symmetrically about the center line of the vessel, a platform overlying the well and spaced above the water to leave a basement between the platform and water, a rotary table supported by the platform, a pipe string, means for supporting the pipe string through the rotary table, a well head member, means for supporting the well head member on the lower end of the pipe string beneath the rotary table and lowering it to the bottom of the water body, means for anchoring the well head member to the formation adjacent the hole, means for disconnecting the pipe string from the well head member, laterally flexible elongated guide means connected to and extending between the well head member and the vessel, a circulating head adapted to be supported on the lower end of the pipe string, means slidably engaging the circulating head and the guide means for lowering the circulating head into engagement with the previously anchored well head member and in registry with the upper end of the hole, and means for releasably connecting the circulating head to the well head member.

11. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying a body of water comprising in combination a floating vessel, a drilling base adapted to rest on the bottom, means adapted to firmly secure the base to the formation adjacent the upper end of the hole, a pair of flexible guide cables fastened to the base at spaced points laterally spaced from the upper end of the hole and extending between the base and the vessel to permit lateral displacement of the vessel with respect to the base during drilling, a drill string supported at and depending from the vessel, a pair of pulleys affixed to the vessel a substantial distance from the point of suspension of the drill string, the guide cables being separately threaded through a separate one of the pulleys, a counter-weight fastened to the upper end of each guide cable, connecting means slideably interconnecting the depending end of the drill string and the guide cables between the drilling base and said pulleys so that as the drill string is lowered it is constrained by the guide cables to register with and enter the upper end of the hole.

12. Apparatus for carrying out operations such as drilling, working and logging in a hole in a formation underlying a body of water comprising in combination a floating vessel, a submerged well head base and means adapted to firmly maintain the base above the formation including a continuous tube connected to and extending from the base to the hole, a laterally flexible elongated guide means connected to and extending between the base and the vessel so as to permit lateral displacement of the vessel during such operations, means mounted on the vessel for supporting and lowering a tool exteriorly of the guide means for carrying out any of said operations from the vessel, means slidably interconnecting the tool and the guide means so that as the tool is lowered it is constrained by the guide means to register with the upper

end of the hole and upon further lowering to progress downwardly in the hole.

13. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying a body of water comprising in combination a floating vessel, a submerged well head base and means adapted to firmly maintain the base above the formation including a continuous tube connected to and extending from said base to the hole, a laterally flexible elongated guide means connected to and extending between the base and vessel so as to permit lateral displacement of the vessel during such operations, a pipe string supported at and depending from the vessel exteriorly of the flexible guide means, connecting means slidably interconnecting the depending end of the pipe string and the guide means so that as the pipe string is lowered it is constrained by the guide means to register the lower end of the string with the upper end of the continuous tube and thereafter constrained by the tube to enter the upper end of the hole.

14. Apparatus for carrying out operations such as drilling and working in a hole in a formation underlying water comprising in combination a floating vessel, a base framework adapted to be submerged approximately beneath the vessel, an elongated conductor pipe attached adjacent one end to the base framework and extending downwardly therefrom into the hole to form a continuous tubular connection between the base framework and the hole and to anchor the framework to the formation, laterally flexible elongated guide means fastened to the base framework laterally of the conductor pipe and depending between the base and vessel so as to permit lateral displacement of the vessel during drilling, means supporting the upper portion of the guide means in proximity to the water surface, a drill string supported at and extending from the vessel, a drilling tool supported on the lower end of the drill string, a circulating head slideably mounted on the drill string, and connecting means interconnecting the circulating head and guide means so that as the circulating head is lowered with the drill string it is constrained by the guide means to register with the conductor pipe and automatically cause the drill tool as the drill string is further lowered to enter the conductor pipe.

References Cited in the file of this patent

UNITED STATES PATENTS

256,658	English	Apr. 18, 1882
285,628	Jones et al.	Sept. 25, 1883
732,925	Decker	July 17, 1903
1,598,439	Hansen	Aug. 31, 1926
1,766,628	Grant	June 24, 1930
1,771,406	Fountain	July 29, 1930
2,200,758	Thaheld	May 14, 1940
2,283,510	Potter	May 19, 1942
2,425,193	Lehr	Aug. 5, 1947
2,476,309	Lang	July 19, 1949
2,606,003	McNeill	Aug. 5, 1952
2,614,804	Carlisle	Oct. 21, 1952
2,650,068	Rand	Aug. 25, 1953
2,665,885	Gignoux	Jan. 12, 1954